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The Effects of Exergaming on the Depressive Symptoms of People With Dementia: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Depressive symptoms are common among people with dementia (PWD). Exergaming consisting of combined cognitive and physical training in gaming is increasingly used to alleviate their depressive symptoms in research. With its potential synergistic neurobiological and psychosocial effects on reducing depressive symptoms among PWD, this review aimed to understand its effectiveness and contents.

Methods: This is a systematic review of the effectiveness of exergames on depressive symptoms among older adults with dementia. A search was conducted on 7 May 2024 of the online databases CINAHL, Embase, PsycINFO, PubMed and the China Academic Journal Network Publishing Database (CNKI). The methodological quality of randomised controlled trials (RCT) and quasi-experimental studies was assessed with RoB2 and ROBINS-I, respectively. A meta-analysis of the included RCTs was conducted.

Results: Six studies consisting of four RCTs and two quasi-experimental studies involving 235 participants with various stages of dementia were included. The meta-analysis showed a significant overall improvement in depression with a large effect size (SMD = 1.46, 95% CI = −2.50, −0.43; $p = 0.006$). Despite high heterogeneity ($I^2 = 91\%$), all studies demonstrated a trend of improvement in depression after the intervention. The exergames adopted in the included trials had the following elements: simultaneous motor-cognitive training, a scoring mechanism and a social play. The dose of exergames ranged from 15 to 60 min per session for at least 8 weeks, with a minimum of two sessions weekly. However, the included studies had a moderate-to-serious risk of bias. The certainty of the evidence was very low.

Conclusion: Exergames could be effective at improving the depressive symptoms of older adults with dementia. Yet, a moderate-to-severe risk of bias shows a rigorous study should be conducted in the future.

Implications for Patient Care: This study provides evidence for healthcare professionals and informal caregivers to use exergames to address depressive symptoms in PWD.

Review Registration: The review was registered on PROSPERO with the reference CRD42022372762.

Summary

- What does this paper contributes to the wider global clinical community?
  - This review showed that exergaming improves depressive symptoms in older adults with dementia, showing a large effect size in the meta-analysis of four RCTs. Yet, a moderate-to-severe risk of bias was found.
  - Successful exergaming interventions included simultaneous motor-cognitive training, a scoring mechanism, and social play, highlighting their importance in therapeutic settings.
  - The encouraging findings provide a basis for futher studies and clinical trials, paving the way for more robust evidence and the development of standardised exergaming protocols in dementia care.

1 | Introduction

Dementia is a neurocognitive disorder that affected more than 57 million individuals worldwide in 2019 (Nichols et al. 2022), 15.9%–41% of whom exhibited symptoms of depression (Asmer et al. 2018; Leung et al. 2021). Depressive symptoms in people with dementia (PWD) are distinguished by a decline in mood-regulating capacity, including a diminished ability to think or concentrate, insomnia, poor appetite, treatment-resistant pain, anhedonia and depressed mood (Burke et al. 2019; Zubenko et al. 2003). These could be associated with adverse health outcomes, such as excess disability in cognitive functions, a worsening quality of life and greater caregiver distress (Cheung, Chien, and Lai 2011; Orgeta et al. 2022). Depressive symptoms might also inhibit some interventions improving PWD's cognition and quality of life (Middelstädt et al. 2016).

To alleviate the depressive symptoms, pharmacological and non-pharmacological treatments are available to PWD. Common antidepressants are tricyclic antidepressants, selective serotonin reuptake inhibitors or selective serotonergic and noradrenergic reuptake inhibitors; however, a systematic review showed that there is still limited evidence of their efficacy among PWD (Dudas et al. 2018). Moreover, these drugs are associated with side effects. For instance, a retrospective cohort study shows the use of trazodone might increase risk of falls or fracture in PWD (Watt et al. 2018). Guidelines from the National Institute for Health and Care Excellence and the World Health Organization suggest non-pharmacological interventions as first-line treatments to manage depressive symptoms in PWD (National Institute for Health and Care Excellence 2018; World Health Organization 2019). A systematic and network meta-analysis comparing the efficacy of pharmacological and non-pharmacological interventions in reducing depressive symptoms among PWD showed that physical exercises combined with cognitive stimulation and social interaction are among the most efficacious of interventions, with greater mean differences than isolated physical exercise, cognitive stimulation, psychotherapies and pharmacological treatments (Watt et al. 2021). As a result, combined physical and cognitive exercises might be considered as one of the most effective types of interventions for reducing depressive symptoms among PWD.

The benefit might be attributed to neurobiological and psychological mechanisms of the combination of physical and cognitive exercises. The guided plasticity facilitation framework is proposed, showing the positive synergistic effects of the combination of physical and cognitive exercises on brain functions (Fissler et al. 2013; Herold et al. 2018). Physical exercises might stimulate neuroplasticity by enhancing the release of brain-derived neurotrophic factors (BDNF) (Gomez-Pinilla et al. 2011; Wang et al. 2022), whereas cognitive stimulation might guide newborn neurons to integrate into the existing neuronal network (Bamidis et al. 2014). It is hypothesised that the benefit might extend to the alleviation of depressive symptoms of PWD. Animal study suggests that higher levels of BDNF in hippocampus might protect the serotonergic fibres from degenerating, thereby reducing depressive symptoms by increasing serotonin secretion and regulating reactivity of the hypothalamic–pituitary–adrenal (HPA) axis to acute stress (Matura et al. 2016). Some studies also show that acute or chronic exercise might stimulate muscles to secrete myokines, which might cross blood–brain barrier to evoke hippocampus to release BDNF, increasing peripheral BDNF concentrations and serum serotonin concentrations in adults (Jemni et al. 2023; Zimmer et al. 2016), potentially leading to the counteracting effect against the pathological pathways of depressive symptoms in patients with dementia, which are neuroinflammation causing the depletion of serotonin secretion and the dysregulation of the HPA axis (Cerejeira, Lagarto, and Mukaetova-Ladinska 2012; Qin et al. 2016; Troubat et al. 2021). Moreover, the synthesis of anandamide might be triggered during physical activity (Tantimonaco et al. 2014). A study shows that anandamide plays an important role in mediating middle-aged adults' HPA activity and restoring noradrenaline levels in the prefrontal cortex to reverse depressive symptoms (Walther et al. 2023). In long term, reduction in neuroinflammation is found with decreasing levels of pro-inflammatory cytokines, such as IL-1β, among participants with major depressive disorder regular physical exercise intervention (Rethorst et al. 2013). Moreover, combining physical training with cognitive training might result in an improvement in depressive symptoms in older adults (Oswald et al. 2006), potentially because cognitive training might lead to functional integration of newborn neurons and synapsis into related brain circuits (Bamidis et al. 2014), such as for memory and problem-solving abilities, which might mediate the relationship between depressive symptoms and functional disability (Gallo et al. 2003). Apart from the neurobiological mechanisms, the benefit of combined cognitive and physical exercise might be explained by psychological mechanisms. Craft and Perna (2004) proposed hypotheses that physical exercise may not only improve the confidence and autonomy of patients with depression when their physical functions and ability to execute daily activities improve, but also stop them from focusing on worries and depressing thoughts. The increase in their sense of control with better physical function can also lead to a decrease in depressing thoughts, such as worrying about memory problems among people with mild to moderate dementia (Kvæl, Bergland, and Telenius 2017), which are common risk factors for developing depressive symptoms in PWD at early stage (Cotter et al. 2018; Halse et al. 2021). Although mechanicalistic explanations underlying the synergistic effects of cognitive and physical exercise on depressive symptoms in PWD were scarcely proposed, supported with the evidence that the benefit of combined cognitive and physical exercise to relieve depressive symptoms might be generalisable to various populations, it shows a great promise as an approach to relieve the depressive symptoms of PWD. However, adhering to the habit of engaging in physical exercise could be challenging for PWD. A systematic review revealed that only an average of 70% of people with cognitive impairment might adhere to physical exercise and more than half might eventually give up (Di Lorito et al. 2020). It is suggested that adherence to exercise might be improved by providing opportunities for socialisation, competitive behaviour, social pressure (e.g., feeling under the scrutiny of others) and by ensuring that people need not travel a long way to access venues for exercising (Cheung et al. 2021; Di Lorito et al. 2020; Katigbak et al. 2018).

Exergames for promoting physical exercise have become more popular, acceptable, affordable and accessible (Stanmore et al. 2017). In the geriatric setting, exergames generally involve 'physical exercise interactively combined with cognitive stimulation in a gaming environment' (Van Santen et al. 2018, p. 742). These features are consistent with the findings of the systematic review, which showed that physical exercises combined with cognitive stimulation and social interaction are the most effective pairing for alleviating depressive symptoms among PWD (Watt et al. 2021). A review of using Nintendo Wii exergames on older adults showed a decrease in depressive symptoms, proposing possible explanations that the real-time feedback, reflections on movements and rewards in a three-dimensional world might strengthen the motivation of participants to adhere to exercise and cause them to feel willing to continue exercising (Chao, Scherer, and Montgomery 2015). Moreover, the gaming components, such as challenges, fantasy, social play, verbal praise, a scoring mechanism and a reward system (Pirovano et al. 2016), might reduce depressive symptoms by enabling PWD interacting with other players or the computer systems to decrease apathy in people with cognitive impairment (Ho, Cheung, Cheng, et al. 2022). A review of exergames on emotional experience showed that games might provide goal-oriented challenges and combine rewards and positive feedback via virtual reward systems and/or verbal compliments from caregivers, which would provide a sense of accomplishment to players (Marques, Uchida, and Barbosa 2023). Apart from motivating players to adhere to physical exercise and psychosocially reducing depressive symptoms, the synergistic effect of combined cognitive and physical exercise in a gaming environment might potentially transfer from improving cognition to reducing depressive symptoms. Some exergames are designed for players to simultaneously accomplish multiple cognitively-demanding tasks in an engaging way (Anguera et al. 2013). Additional cognitive stimulation benefits might be brought by engaging in multiple cognitively demanding tasks during playing exergames (Anguera et al. 2013). Reviews have shown that exergames apparently improved episodic memory and executive function in PWD (Swinnen, Vandenbulcke, and Vancampfort 2022) as well as increased BDNF levels, a crucial biomarker associated with neuroplasticity (Stojan and Voelcker-Rehage 2019). Therefore, exergaming has high potential as a new approach to managing depression in PWD and is attracting more attention in the field. The rationale for supporting the use of exergaming for this purpose is illustrated in Figure 1.

Two systematic reviews evaluating the effects of exergaming on PWD have been published (Swinnen, Vandenbulcke, and Vancampfort 2022; Van Santen et al. 2018). They found only one study examining the effect of exergaming on depressive symptoms in PWD and its non-significant effect (Bamidis et al. 2015). Technological therapeutic programmes have been emerging quickly, especially during the period of the COVID-19 pandemic (Barbosa et al. 2024). Therefore, with consideration of the most updated evidence, there is a pressing need to update the last reviews by including the newest evidence. Moreover, a review of the effect of exergaming on depression in adults mentioned that variation in the practice of exergames might lead to difficulty in future development and implementation of exergames with positive results (Li, Theng, and Foo 2016). Although published reviews about exergames to alleviate depression focused on the effect (Li, Theng, and Foo 2016; Swinnen, Vandenbulcke, and Vancampfort 2022; Van Santen et al. 2018), analysis of the content of exergames seems to be scarce. Torre and Temprado (2022) developed a structured framework to categorise combined training interventions and utilised it to analyse the effect of exergames on cognition in older adults. Although the framework with seven constructs (i.e., stimuli, settings, targets, markers, outcomes, mechanisms and moderators) might provide a thorough illustration of variables influencing training effectiveness, concerns arise over inadequate analysis of game design of exergames in the review (Torre and Temprado 2022). Especially as gaming might also be a key to alleviating depressive symptoms in PWD, it is important to adapt the current framework to include gaming as a potential therapeutic stimulus in the present review. It is significant to understand the updated evidence of the effectiveness of various exergames and the content of effective exergames, which might help researchers and healthcare professionals make informed decisions for developing and using exergames respectively.

2 | Aim

The aim of this study was to understand the state-of-the-art in exergaming for alleviating the depressive symptoms of PWD. We seek to answer two research questions: (a) What are the effects of exergaming on the depressive symptoms of PWD? (b) What are the contents of the games?

3 | Methods

This is a systematic review and meta-analysis, reported according to the Preferred Reporting Items for Systematic Reviews

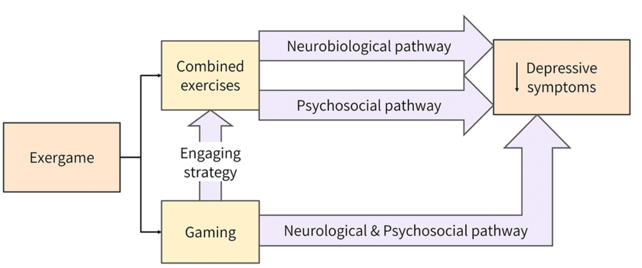

FIGURE 1 | Conceptual framework showing the relationship between exergaming and depressive symptoms in PwD. [Colour figure can be viewed at wileyonlinelibrary.com]

and Meta-Analyses (PRISMA) guidelines (Page et al. 2021) (Appendix S1). This review protocol was registered on PROSPERO (CRD42022372762).

3.1 | Eligibility Criteria

Any experimental study designs with pretest and posttest evaluation, which might include randomised controlled trials (RCTs) and non-randomised trials, were eligible for inclusion in the review. To comprehensively review as much evidence related to exergaming for addressing depressive symptoms as possible and addressing the limitations of the previous two reviews, non-randomised trials were included. Particularly in emerging technology research, non-randomised trials might be more frequently performed as they are quick and easy to conduct with sufficient information about the effect of the interventions (Chambers, Rodgers, and Woolacott 2009). The PICO (Participant, Interventions, Comparison, Outcome) framework (McKenzie et al. 2019) was employed to devise the eligibility criteria for this systematic review.

3.1.1 | Population

Studies examining the effects of exergaming on PWD were included. These studies needed to at least describe the relevant condition that was diagnosed or verified against any established clinical or research diagnostic criteria. However, studies on people with subjective cognitive decline or mild cognitive impairment were not eligible. In terms of studies combining PWD and other population groups (such as stroke), the results had to be reported in a way that allowed the data of PWD be extracted.

3.1.2 | Intervention

Eligible studies should examine exergaming, which is defined as 'physical exercise interactively combined with cognitive stimulation in a gaming environment' (Van Santen et al. 2018, p. 742). It can be carried out in a group or on an individual basis. No restrictions were made regarding intervention protocol, intensity, dosage, overall duration of the intervention or number of sessions.

3.1.3 | Comparison

Studies were eligible no matter whether there were comparators. If there are comparators, they could be any interventions without exergaming, including traditional exercises, usual care, waiting list control or no treatment.

3.1.4 | Outcome

For this systematic review, studies in which depression was measured as an outcome using a validated instrument were considered. Examples of validated instruments include but do not limit the eligibility criteria to Beck Depression Inventory-II, the Cornell scale for depression in dementia and the Geriatric Depression Scale (Watt et al. 2021).

3.2 | Information Sources and Search Strategy

Five electronic databases were searched, namely Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, PsycINFO, PubMed and the China Academic Journal Network Publishing Database (CNKI). The reference lists of eligible studies or relevant reviews were searched to identify additional studies. The search strategy combined keywords and MeSH using Boolean operators, around the PICO mentioned above. Keywords for the population domain included 'dement*', 'major neurocognitive disorder' and 'Alzheimer*'. Keywords for the intervention domain included exergam*, physical activity, activ*, rehab*, sport, exercise, gam*, play, video, virtual reality, human computer interaction, augment* reality, electronic, Wii, Eye Toy, Xbox, mouvmat, DDR, active arcade, Nintendo Switch, Eyetoy, Kinect, Playstation and Dance Revolution. The keyword for the outcome domain was depress*. Details of the search strategies are provided in the Appendix S2. The search was conducted on 7 May 2024.

No specific restrictions (such as timeframe or study design) were set during the database search to ensure that the search captured as many eligible studies as possible, according to the suggestion of Lefebvre et al. (2019). However, only studies written in English and Chinese were included in this review.

3.3 | Selection Process

Retrieved studies were imported into Endnote 20 (The EndNote Team 2013) to remove duplicates. The titles and abstracts were first screened independently by two reviewers (JT and KC) against the eligibility criteria, as detailed in Section 3.1, followed by full-text screening. The inter-rater agreement in terms of Cohen's kappa was 0.91 during title and abstract screening, and 1.00 during full-text screening, shown in Figure 2 and indicating almost perfect agreement (Landis and Koch 1977). Any disagreements at each stage of the screening were resolved by discussions among the team.

3.4 | Data Extraction

Data extraction was conducted using a modified version of a standardised data extraction form from the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al. 2022). Data were extracted in duplicate independently by two reviewers and checked by the third reviewer. The inter-rater agreement in terms of Cohen's kappa was 1.00 during data extraction, indicating perfect agreement (Landis and Koch 1977). In cases where unclear or missing information was reported in the included studies, the original authors of that article were contacted for information. The extracted data included information about the publication, study design, participants' characteristics, completion adherence (i.e., percentage of participants who completed the study in each group; Di Lorito et al. 2020), design of the intervention and outcomes.

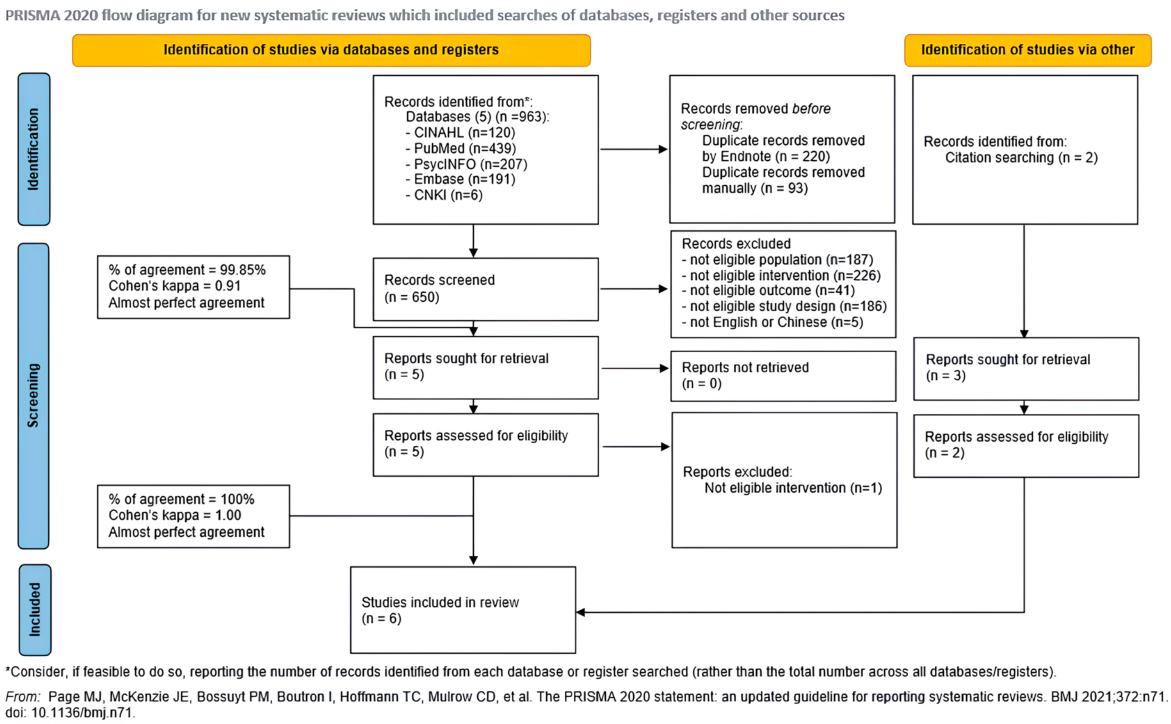

FIGURE 2 | Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart of the selection process. [Colour figure can be viewed at wileyonlinelibrary.com]

Given the complexity of exergames, we attempted to map the content of the exergames on the basis of an adapted framework (Torre and Temprado 2022). The framework distinguished:

3.4.1 | Stimuli

These included the type of training and gaming elements. According to the categorisation of combined training for older adults (Torre and Temprado 2021), the type of training was identified as physical-cognitive training (PCT), which combines cognitive stimulation with aerobic and/or muscular resistance training, motor-cognitive training (MCT), which combines complex motor skills training with additional cognitive stimulation and multi-domain training (MDT), which includes aerobic and/or muscular resistance training, complex motor skills training and additional cognitive stimulation. The combined training can either be simultaneous or sequential (Torre and Temprado 2021). Another stimulus was gaming elements, which were identified on the basis of the recommendations for good game design for older adults adopted from Pirovano et al. (2016): intrinsic motivational factors, built inside exergames, include challenge, fantasy, curiosity, sensation and social play while extrinsic ones comprise verbal praise, scoring mechanisms and reward systems, which are independent of the games.

3.4.2 | Settings

These include the organisation of the exergaming interventions being carried out, with respect to exercise intensity and exercise duration, training frequency, training density and training duration, as defined by Herold et al. (2019), training location, training administration (i.e., performed individually, in a group or both), supervision of training, individualisation of training (i.e., generic or tailored) and body position during training, as defined by Manser, Herold, and de Bruin (2024), as well as the technological devices used.

3.4.3 | Mechanisms

The theoretical frameworks, models or specific physiological, neurobiological and psychosocial mechanisms proposed in the included studies to explain their results were extracted.

3.4.4 | Moderators

Information about the settings of training interventions, participant characteristics and methodologies of included studies, as mentioned in Torre and Temprado (2022), was extracted.

3.4.5 | Targets

The target refers to the outcomes to be observed in the training interventions (Torre and Temprado 2021), and our outcomes of interest (i.e., depressive symptoms) were extracted.

3.4.6 | Markers

The tests used to assess the targeted outcomes were extracted (Torre and Temprado 2021).

3.4.7 | Outcomes

The observed effects of the training were extracted (Torre and Temprado 2021).

3.5 | Assessing the Risk of Bias in the Studies and Certainty of Evidence

For the included RCTs, Version 2 of the Cochrane risk-of-bias tool for randomised trials (RoB2) was used to assess the risk of bias, as suggested by Higgins et al. (2022). The tool consists of five domains: randomisation process, deviations from the intended interventions, missing outcome data, measurement of the outcome and selection of the reported results. The response options for each domain and the overall judgement are 'low risk of bias', 'some concerns' and 'high risk of bias'. For non-RCT, the Risk of Bias in Nonrandomised Studies of Interventions (ROBINS-I) tool was used (Higgins et al. 2022). Based on the tool, we made a judgement on the 'low/ moderate/ serious/ critical/ no information' risk of bias of the studies in seven domains (confounding, selection of participants into the study, classification of interventions, deviations from the intended intervention, missing data, measurement of outcomes and selection of the reported result). Two reviewers (JT and KC) independently applied the tool to each eligible study, recording justifications and supporting evidence for judgements of the risk of bias for each domain. Any differences in judgement were resolved by discussion to achieve a consensus. The inter-rater agreement in terms of Cohen's kappa was 1.00 during the risk of bias assessment, indicating perfect agreement (Landis and Koch 1977).

The certainty of evidence was independently assessed by DC and JT. Five GRADE domains, including risk of bias, inconsistency, indirectness, imprecision and publication bias, were considered with RCTs, which contributed data to the meta-analysis (Higgins et al. 2022). The response options for the overall judgement are 'very low', 'low', 'moderate' and 'high' certainty. GRADEpro GDT software (McMaster University and Evidence Prime 2024) was used to prepare the summary of findings table.

3.6 | Effect Measures

The primary outcome of interest was the level of depression of PWD, measured using validated instruments. For each study, means and standard deviations in each intervention group at baseline and post-intervention were extracted. Among RCT studies, where possible, information based on intention-to-treat analyses was extracted. Otherwise, means and standard deviations reported for trial completers were used. If the exergame and control groups had a similar pre-intervention level of depression and the change-from-baseline standard deviations were not reported in included studies, effect size reflecting post-intervention differences between the exergame group and the control group was calculated. Otherwise, effect measures were based on the change from baseline.

3.7 | Data Synthesis

Only RCTs were included in the meta-analysis. Data were analysed using RevMan 5.4 to combine the extracted data (The Cochrane Collaboration 2020). The summary measure was computed using a random effects model, with standard mean differences with 95% confidence intervals. The test for overall effect was evaluated using Z-statistics, with $p < 0.05$ considered statistically significant. Heterogeneity between studies was assessed using the Cochran Q (chi-squared test) and I^2 statistics (Higgins et al. 2022). An I^2 statistic of over 75% was regarded as indicating considerable heterogeneity (Higgins et al. 2022). A random effects model was used to pool the results from individual studies, as there was methodological heterogeneity among the studies because of differences in the instruments and game design/platforms that were used. Publication bias was visually inspected using a funnel plot and determined statistically using Egger's regression test if there were more than 10 studies in a meta-analysis (Higgins et al. 2022). The effect size was evaluated in accordance with Cohen's criteria: a standardised mean difference (SMD) of ≥ 0.20 and < 0.50 was considered small; ≥ 0.50 and < 0.8 moderate; and ≥ 0.8 large (Cohen 1992). A sensitivity analysis was carried out by conducting a meta-analysis that excluded a study with outcome measures different from the other studies, or one with the highest risk of bias, to ensure the robustness of the conclusion.

The content of the exergames was summarised and is shown in a table, to address the second research question.

4 | Results

4.1 | Search Results

Nine hundred sixty-three articles were identified from the electronic database and 313 duplicates were removed with Endnote followed by a manual search. Ineligible studies were those with an inappropriate study population, an intervention not related to exergames, outcomes not related to depressive symptoms or with a non-experimental design. In the end, the full-text of five articles were screened and four were deemed to be eligible (Burdea et al. 2015; Swinnen et al. 2021; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020). After adding two eligible studies identified from the reference lists of included studies (Xie et al. 2020; Yamaguchi, Maki, and Takahashi 2011), six articles in total were included in this review. See Figure 2 for details.

4.2 | Study Characteristics

An overview of the six included studies is shown in Table 1. These studies were conducted from 2011 to 2021, in Japan, the United States, China and Belgium. There were two single-group pretest-posttest design studies, and four RCTs . The sample size ranged from 9 to 76 participants, for a total sample size of all included studies of 235 (excluding 20 recruited participants who were excluded from the analysis by the original authors; Swinnen et al. 2021; Zheng, Yu, and Chen 2022), comprised of 99 males and 136 females. The

TABLE 1 | Characteristics of the included studies.

Study	Yamaguchi, Maki, and Takahashi (2011)	Burdea et al. (2015)	Xie et al. (2020)	Zhu, Zhou, and Yu (2020)	Swinnen et al. (2021)	Zheng, Yu, and Chen (2022)
Country	Japan	USA	China	China	Belgium	China
Study design	Single-group pretest-posttest	Single-group pretest-posttest	RCT	RCT	RCT	RCT
Number of participants						
IG						
Baseline	9	10	28	35	28	24
Post	9	10	28	35	23	18
Completion adherence	100%	100%	100%	100%	82%	75%
CG						
Baseline	NA	NA	29	41	27	24
Post	NA	NA	29	41	22	20
Completion adherence	NA	NA	100%	100%	81%	83%
Participants' mean age in year (SD)	88.9 (4.9)	63.4 (6.0)	IG: 67.6 (8.8) CG: 68.8 (9.6)	IG: 72.8 (3.0) CG: 73.1 (3.1)	IG: 84.7 (5.6) CG: 85.3 (6.5)	IG: 81.7 (5.8) CG: 84.3 (5.5)
Male participants ratio	33.3%	63.6%	47.4%	56.6%	22.2%	23.7%
Severity of dementia	Mild to moderate	Mild to severe	Mild to moderate	Moderate to severe	Mild to moderate	Mild to severe
Setting	Residential facility	Residential facility	Mixed[a]	Hospital	Residential facility	Mixed[a]
Game	Hot-Plus video games	BrightBrainer video games	Immersive Virtual reality practical games	Fruit Ninja video game	Standing exergaming programme	Fruit Ninja video game
Type of combined training	MCT	MCT	MCT	MCT	MCT	MCT
Simultaneous/sequential	Simultaneous	Sequential	Simultaneous	Simultaneous	Simultaneous	Simultaneous
Gaming element						
Challenges [I]	√	√	√		√	
Social play [I]			√	√		√
Fantasy [I]					√	

(Continues)

TABLE 1 | (Continued)

Study	**Yamaguchi, Maki, and Takahashi (2011)**	**Burdea et al. (2015)**	**Xie et al. (2020)**	**Zhu, Zhou, and Yu (2020)**	**Swinnen et al. (2021)**	**Zheng, Yu, and Chen (2022)**
Scoring [E]	√	√	√	√	√	√
Verbal praise [E]	√					√
Virtual reward [E]		√				
Devices used	XaviXPORT Console; TV	BrightBrainer system including a computer, a bimanual game controller, a remote clinical server and a library of simulations	HTC VIVE PRO Headset	LED monitor; Xbox 360 Console with Kinect	Dividat Senso exergame device, computer, a TV	Xbox 360 Console with Kinect
Body position	N.M.	Sitting	N.M.	N.M.	Standing	Sitting
Exercise duration (min)	Not mentioned	20–40	30	60	15	60
Training frequency (session per week)	1	2	2	5	3	5
Training duration (week)	10	8	12	8	8	8
Training location	Residential facility	Residential facility	N.M.	Hospital	Residential facility	N.M.
Training administration (Group/individual)	Group (no. of people not specified)	Individual	Group (four to five people/group)	Group (five people/group)	Individual	Group (six people/group)
Supervision of training (Interventionist)	Trained caregiver	Researcher	Researcher	Researcher	Physio-therapist	Researcher
Comparator	No CG	No CG	Played the same game via iPad without physical activity	Treatment as usual	Watched & listened to music videos	Treatment as usual
Outcome measures for depression (range of scores)	MOSES-D (8–37)	BDI (0–63)	HAMD (0–54)	CSDD (0–38)	CSDD (0–38)	CSDD (0–38)
p value of pre-intervention comparison between groups	NA	NA	0.666	0.862	0.310	0.974
Mean (SD) at baseline; post-intervention						

(Continues)

TABLE 1 | (Continued)

Study	Yamaguchi, Maki, and Takahashi (2011)	Burdea et al. (2015)	Xie et al. (2020)	Zhu, Zhou, and Yu (2020)	Swinnen et al. (2021)	Zheng, Yu, and Chen (2022)
Intervention group	12.36 (3.08); 10.46 (2.58) $p=0.13$	8.0 (6.9); 5.5 (6.2) $p=0.056$	18.14 (4.78); 12.96 (3.48) $p<0.001$	15.24 (1.73); 7.45 (0.72) $p<0.05$	7.0 (6.4); 3.0 (4.4) $p<0.001$	15.67 (5.88); 7.61 (4.55) $p<0.001$
Comparison group	NA	NA	17.59 (4.89); 15.27 (4.23)	15.31 (1.76); 10.98 (1.43)	5.3 (4.5); 9.3 (6.7)	15.75 (9.36); 17.60 (10.55)

Note: Remarks: BDI, Beck Depression Inventory—Revised; CG, control group; CSDD, Cornell Scale for Depression in Dementia; [E], extrinsic factor; HAMD, Hamilton Depression Rating Scale; [I], intrinsic factor; IG, intervention group; MCT, motor-cognitive training; MOSES-D, Multidimensional Observation Scale for Elderly Subjects—Depression subscale; NA, not applicable; RCT, randomised controlled trial; SD, standard deviation.
[a]Mixed setting means participant recruitment was taken place in the community and residential facility.

completion adherence ranged from 75% to 100%. The mean age of the final sample among these six studies ranged from 64.3 to 88.9 years. All of the participants had some form of dementia, from mild to severe dementia, and had been recruited from community, hospital or residential facilities. See Table 1 for details.

4.3 | Exergame Contents

Regarding the type of combined training, all of the included studies consisted of motor-cognitive training. All interventions were targeted at motor coordination. Hot-plus video games required participants to use the upper extremities to grab coins, which appeared on the TV screen or to tap feet on a mat in order to synchronise with the balls bouncing on the drums on the TV screen (Yamaguchi, Maki, and Takahashi 2011). BrightBrainer videogames consisted of three games, which are Breakout 3D, Kites and Musical Drums, requiring players to move to respond to visual or auditory cues (Burdea et al. 2015). Exergames developed by Swinnen et al. (2021) required players to interact with the game interface by pushing one foot on one of the four different arrows on the device. The task in Fruit Ninja video game for players was to use their upper extremities as an imaginary sword to cut fruits on screen (Xie et al. 2020; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020). Only one exergame included balance training (Swinnen et al. 2021). All interventions indicated their targets at cognitive abilities were hand-eye coordination and focused attention, whereas BrightBrainer videogames contained other games, such as Card Island to strengthen short-term memory, and Remember that Card for long-term memory (Burdea et al. 2015). Only one study included flexibility strengthening (Swinnen et al. 2021). Most of the combined training were simultaneous (Swinnen et al. 2021; Xie et al. 2020; Yamaguchi, Maki, and Takahashi 2011; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020), whereas BrightBrainer videogames trained motor and cognitive skills in a mixed manner, which train motor skills initially, followed by a game for simultaneous combined training and a game for cognitive training (Burdea et al. 2015). The body position of the training was standing with stepping movements (Swinnen et al. 2021), sitting (Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020) or not reported.

Regarding gaming elements, all of the studies incorporated intrinsically fun factors into the structure of their games, such as challenges, fantasy, curiosity and social play, as well as extrinsic motivational elements, such as verbal praise, a scoring mechanism and a virtual reward system, based on the classification suggested by Pirovano et al. (2016). The scoring mechanism was the most common strategy that was adopted, followed by challenges and social play.

The games could be designed to allow direct or indirect interactions between the participants and the system (Andrade Ferreira et al. 2020). Games that allow direct interaction require the players to play the game using parts of their body instead of using a controller (Andrade Ferreira et al. 2020); this was the design in most of the included studies. In the study of Yamaguchi, Maki, and Takahashi (2011), the participants were required to grasp coins with their hands while wearing a sensor band or to tap their feet on a sensor mat to music. The participants in Zhu, Zhou, and Yu (2020) and Zheng, Yu, and Chen (2022) played Fruit Ninja video games by thrusting their upper arm out as if they were holding an imaginary sword to cut fruits before they dropped to the bottom of the screen. These two games that were employed in the three included studies were designed with a scoring system counting the players' reaction time. The exergame designed in Swinnen et al. (2021) required the participants to put one foot on one of the four arrows pointing in different directions (left/right/up/down) that were printed on a Dividat Senso platform equipped with pressure sensors, according to the prompts shown on the screen. Games that require the player to use handheld controllers to translate human actions in response to the prompts are classified as indirect interaction games (Andrade Ferreira et al. 2020). The BrightBrainer video games investigated in the study of Burdea et al. (2015), required the players to utilise the Razer Hydra bimanual controller connected to a computer to play the games. The controller was designed with an analogue trigger-like switch that detects the degree of flexion/extension of the index finger as a part of an avatar control or for the setting of dual tasks. Six game scenes were developed for training cognitive functions, namely *Breakout 3D*, *Kites*, *Drums*, *Card Island*, *Remember that Card*, and *Pick and Place*. The scoring was based on getting an accurate response to the cognitive tasks. In the study of Xie et al. (2020), the participants wore the HTC VIVE PRO Headset to immerse themselves in the virtual reality, and played the games using the controllers. The scenes, which were designed in-house, were cutting fruits, shooting, archery and throwing. The scoring mechanism was not described in detail.

The exercise duration per session ranged from 15 to 60 min. The training frequency was one session per week (Yamaguchi, Maki, and Takahashi 2011), two sessions per week (Burdea et al. 2015; Xie et al. 2020), three sessions per week (Swinnen et al. 2021) or five sessions per week (Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020). The training duration ranged from 8 to 12 weeks. Significant results were shown in interventions of at least 15 min per session and no less than 8 weeks, with a minimum of two sessions weekly. Some interventions were performed on-site (i.e., residential facility or hospital) (Swinnen et al. 2021; Yamaguchi, Maki, and Takahashi 2011; Zhu, Zhou, and Yu 2020). In two of the studies, the exergames were administered in an individual setting (Burdea et al. 2015; Swinnen et al. 2021), whereas the others were in a group setting (Xie et al. 2020; Yamaguchi, Maki, and Takahashi 2011; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020). Professionals or trained caregivers supervised the training. In four RCTs, two studies used an active control, such as playing the same game via iPad, where no physical activity was involved (Xie et al. 2020), as well as watching and listening to music videos (Swinnen et al. 2021), whereas others studies used treatment as usual as their control (Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020). Few information was provided about exercise intensity, training density, individualisation of training and their mechanisms.

4.4 | Risk of Bias in Studies

There were generally some doubts about the quality of the studies or about a high risk of bias (Figures 3 and 4) because of some concerns in the domain of 'bias due to deviations from the intended intervention', where an exergame was used as a psychosocial intervention, in which the participants were generally aware of their assigned intervention during the trial. The overall risk of bias of Zheng's article was rated as high, since data on less than 95% of the participants were available with no reasons given, and there were differences in the proportion of missing outcome data between the intervention group and control groups (Zheng, Yu, and Chen 2022). Another study was evaluated as being of a serious risk of bias because the intervention group was not clearly defined and varying levels of knowledge among the caregivers might have led to deviations from the intended intervention and differences in the way that the outcome was measured (Yamaguchi, Maki, and Takahashi 2011).

4.5 | Effects of Exergames on Depression in Dementia

The Cornell Scale for Depression in Dementia was used in 50% of the included studies for measuring depressive symptoms (Swinnen et al. 2021; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020), whereas the other studies employed the Multidimensional Observation Scale for Elderly Subject Depression Subscale (Yamaguchi, Maki, and Takahashi 2011), the Beck Depression Inventory—Revised Version (Burdea et al. 2015) and the Hamilton Depression Rating Scale (Xie et al. 2020). In all of these scales, higher scores indicate more severe depression. The intervention group of all six included studies, consisting of both quasi-experimental studies and RCTs, showed a trend of improvement in depression in the intervention group by comparing the post-score with the pre-score. However, only the four RCT studies with a sample size of larger than 10 yielded a statistically significant difference from baseline to post-intervention (Swinnen et al. 2021; Xie et al. 2020; Zheng, Yu, and Chen 2022; Zhu, Zhou, and Yu 2020).

As the exergame and control groups had a similar pre-intervention level of depression, with changes-from-baseline standard deviations not reported in all included studies, effect size reflecting post-intervention differences between the exergame group and the control group was calculated. The meta-analysis based on these four RCT studies was conducted to estimate the overall effects of exergames on depression among 216 participants with dementia. A significant overall improvement was found in depression (SMD = 1.46, 95% CI = −2.50, −0.43; $p = 0.006$; See Figure 5 for the forest plot for depression of all included studies). The p-value for the Cochran's Q test was < 0.01 and $I^2 = 91\%$, suggesting high heterogeneity.

Sensitivity analyses revealed a significant overall improvement in depression remains unchanged when excluding the study with a high risk of bias (Zheng, Yu, and Chen 2022) (shown in Figure 6) or the study that used a different measuring tool (Xie et al. 2020) (shown in Figure 7).

4.6 | Certainty of Evidence

The certainty of evidence was rated as very low (Table 2).

5 | Discussion

This updated systematic review aimed to synthesise the existing available evidence on the effect of exergaming on depressive

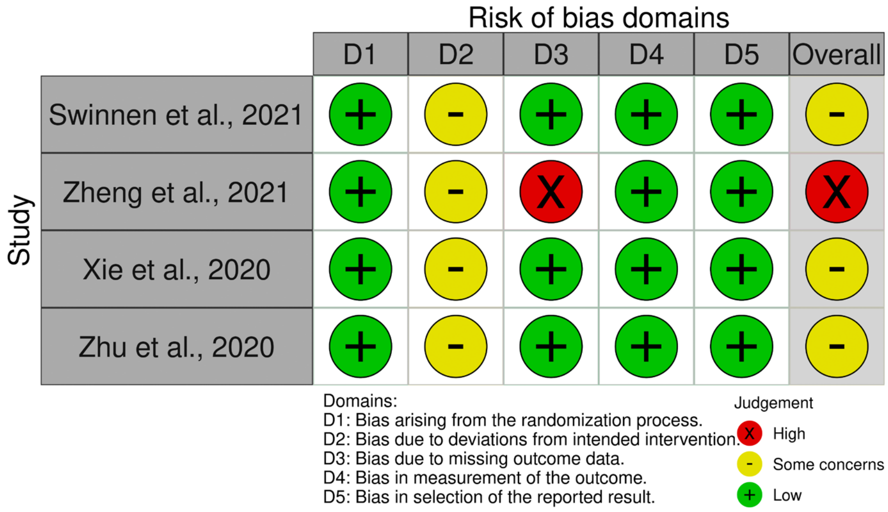

FIGURE 3 | Risk of bias assessment by RoB2. [Colour figure can be viewed at wileyonlinelibrary.com]

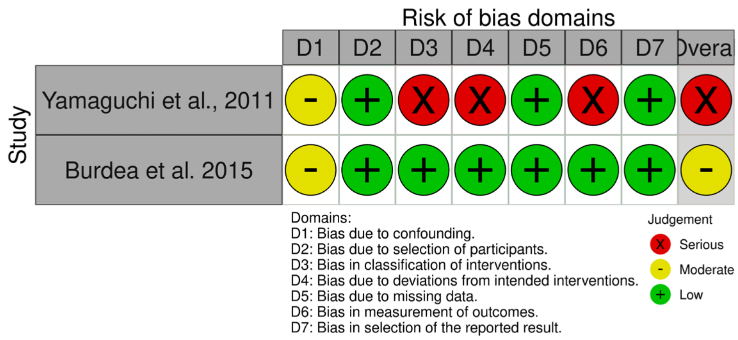

FIGURE 4 | Risk of bias assessment by ROBINS-I. [Colour figure can be viewed at wileyonlinelibrary.com]

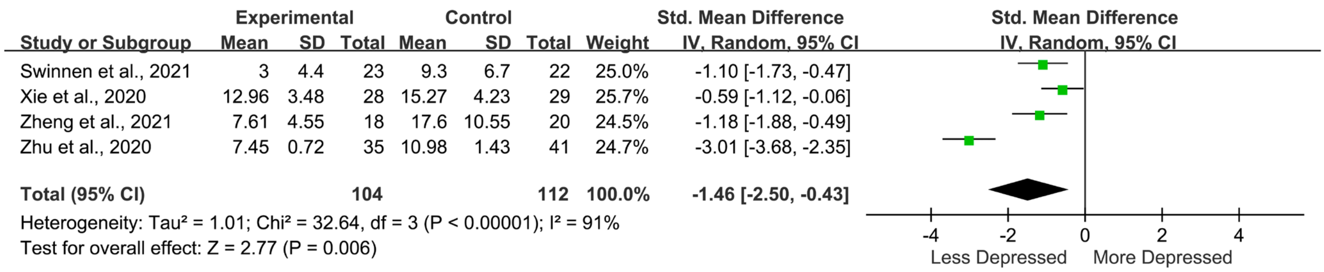

FIGURE 5 | Forest plots for depression of all included studies. [Colour figure can be viewed at wileyonlinelibrary.com]

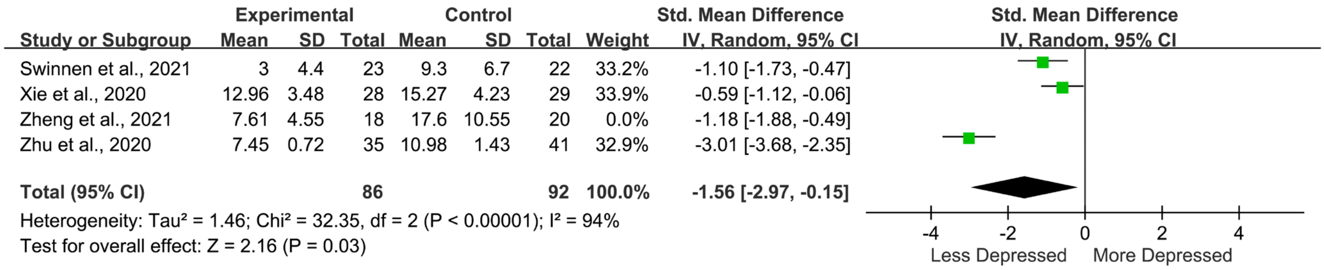

FIGURE 6 | Forest plots for depression of all included studies excluding Zheng, Yu, and Chen (2022), which had a high risk of bias. [Colour figure can be viewed at wileyonlinelibrary.com]

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Swinnen et al., 2021	3	4.4	23	9.3	6.7	22	33.7%	-1.10 [-1.73, -0.47]
Xie et al., 2020	12.96	3.48	28	15.27	4.23	29	0.0%	-0.59 [-1.12, -0.06]
Zheng et al., 2021	7.61	4.55	18	17.6	10.55	20	33.0%	-1.18 [-1.88, -0.49]
Zhu et al., 2020	7.45	0.72	35	10.98	1.43	41	33.3%	-3.01 [-3.68, -2.35]
Total (95% CI)			**76**			**83**	**100.0%**	**-1.76 [-2.99, -0.54]**

Heterogeneity: Tau² = 1.06; Chi² = 20.46, df = 2 (P < 0.0001); I² = 90%
Test for overall effect: Z = 2.82 (P = 0.005)

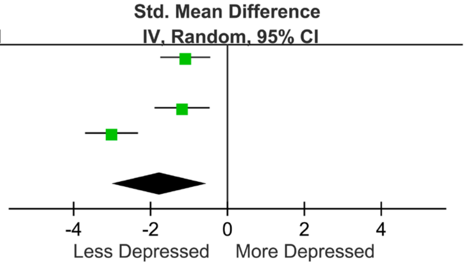

FIGURE 7 | Forest plots for depression of all included studies excluding (Xie et al. 2020), which used the Hamilton Rating Scale for Depression instead of the Cornell Scale for Depression in Dementia. [Colour figure can be viewed at wileyonlinelibrary.com]

symptoms in dementia with the first meta-analysis of included RCTs as well as the content of exergames according to an adapted framework. The results of the meta-analysis based on four RCTs indicated that exergaming appeared to be effective, with a large effect size compared with the control group. However, due to heterogeneity and limited study inclusion, the estimated effect size remains doubtful. In addition, the certainty of evidence is rated very low. The designs of the exergames applied in the included studies were summarised in terms of types of combined training, gaming elements, and other training variables. Simultaneous motor-cognitive training, a scoring mechanism, and social play were commonly involved in the games. The dose of exergames ranged from 15 to 60 min per session for at least 8 weeks, with a minimum of two sessions weekly.

5.1 | Effects

Discordant results are found when comparing insignificant anti-depressive effects in the previous systematic reviews. The systematic review conducted by Swinnen, Vandenbulcke, and Vancampfort (2022) and Van Santen et al. (2018) systematically evaluated the efficacy of exergames in individuals with major neurocognitive disorders. However, they included only one study involving older adults with or without neurocognitive disorders and targetingdepressive symptom as an outcome (Bamidis et al. 2015), and concluded that the effectiveness of exergaming on depressive symptom is not significant. Our review addressed the knowledge gap by including more recently published articles because the fast development of technologies facilitates exergames more feasible to achieve the outcome (Barbosa et al. 2024). In contrast, the results of this review are consistent with existing reviews investigating the effects of exergaming on the depressive symptoms of adults or older adults without dementia. The reviews supported that adults and older adults could benefit from exergaming regarding depression improvement (Drazich et al. 2020; Huang et al. 2022; Li, Theng, and Foo 2016; Yen and Chiu 2021). The consistent results might show that exergames are not only effective on older adults without dementia but also PWD.

5.2 | Contents of Exergames for PWD

Simultaneous motor-cognitive training was chosen as the type of training in all included studies. There are similarities between the findings of this review and another review of exergames on brain and cognition in older adults, in which motor-cognitive training was one of the dominant modes of combined training (Torre and Temprado 2022). These results confirmed a need to analyse the type of training, rather than focusing on the effect and mixing of exergames in most reviews, to provide evidence to inform the development and implementation of exergames for PWD. However, the underlying mechanistic explanations for the observed results were not reported. Also, the included studies used comparators, such as playing the same game via iPad or watching and listening to music videos rather than involving separated cognitive, motor and physical training. The evidence that the anti-depressive effect of combining cognitive and motor training is superior to separated ones in PWD remains unclear.

Our findings showed that all included studies employed scoring mechanisms, potentially a crucial moderator for training effectiveness on depressive symptoms. A scoping review on the usability and acceptability of balance exergames in older adults found immediate feedback, competition and challenge might be positive game aspects for older adults to use (Nawaz et al. 2016). Via scoring mechanisms, players can immediately receive feedback about their performance and compare their performance with their groupmates or pre-intervention status. It is also believed that the scores may provide a sense of self-efficacy to the participants in real-time, potentially as a motivating factor for older adults to engage in the exergames (Ning et al. 2022). The inclusion of scoring mechanisms in exergames appears to play a significant role in modulating training effectiveness on depressive symptoms.

In addition, the exergames applied in 75% of the included RCTs carried out on a group basis, had a significant positive effect on depressive symptoms. We suggested that the social interaction facilitated by the exergaming intervention contributed greatly to this result. Consistent with a network meta-analysis comparing the effectiveness of interventions for alleviating depressive symptoms among PWD, social interaction, which combines physical exercise and cognitive stimulation was significantly larger than that of exercise alone (Watt et al. 2021). A scoping review of usability and acceptability of balance exergames in older adults found playing together in groups might be a positive game aspect for older adults to use (Nawaz et al. 2016). Given that older adults may experience social isolation because of physical disabilities or other age-related issues (Cheung, Kwan, et al. 2020; Ho, Cheung, et al. 2021), or to social restrictions during the pandemic (Ho, Cheung, Lee, et al. 2022; Ho, Mak, et al. 2021; Kwan et al. 2021), this may suggest that social interactions can alleviate the negative impacts (Ho et al. 2023). However, it is worth noting that although participating in the intervention encouraged social interactions and friendships, the immediate sense of loss of social contact or friendships was reported once the intervention ended and the participants' involvement ceased among people living with early dementia (Sprange et al. 2021).

Employing technology in caring for older people with cognitive impairment is becoming more popular and is believed to yield better therapeutic results or to facilitate the implementation of interventions. For instance, e-Health plays a prominent role in the promotion of physical activity among older adults with cognitive impairment and frailty (Kwan, Lee, et al. 2020; Kwan, Salihu, et al. 2020). The use of virtual reality is also becoming common in dementia care or caregiver training (Ho, Cheung, Cheng, et al. 2022; Huang et al. 2024). Nevertheless, the present findings showcase that most interventions used researchers as intervention facilitators, instead of caregivers. With a user-friendly interface, it is believed that family caregivers or trained volunteers can provide exergaming or other e-Health interventions to enhance the sustainability of the intervention to yield long-term benefits (Cheung, Ho, Chan, et al. 2022; Cheung, Ho, Kwok, et al. 2022; Liu et al. 2023).

5.3 | Limitations

This review and meta-analysis is not without limitations. A variety of terms related to exergaming were used to search the literature. Chinese translations of these terms were also used. Although a university librarian was consulted and confirmed that the search strategies were appropriate, we could not eliminate the slim possibility that some eligible studies were missed, especially when an uncommon commercial brand name was used in the title. In addition, the total number of included studies was small, with the inclusion of non-randomised studies. The publication bias testing with the Egger plot could not be carried out. Schulz et al. (2022) emphasised the importance of qualitative evidence synthesis when dealing with a limited number of studies in meta-analyses. Additionally, Bender et al. (2016) suggested that it is occasionally feasible to draw conclusions even with very few studies (such as one or two). In our endeavour, we aim to employ the concept of conclusive effect (Bender et al. 2018). Our qualitative summary has demonstrated clear and sufficient evidence of intervention effect that was supported by all individual studies showcasing significant treatment effects. However, although the pooled estimate from the meta-analysis is also significant and with a large effect size, the estimated effect size remains inconclusive and uncertain. This uncertainty is illustrated by the wide estimate interval, due to heterogeneity and the limited inclusion of studies. In the future, when more primary studies have been conducted, we recommend that a subgroup analysis based on the severity of the participants' dementia be conducted, or a meta-regression be carried out to determine whether the duration and course of an exergame protocol might have an impact on the effects. After all, a network meta-analysis can be carried out to compare the effects of an exergame with other interventions that might alleviate depression in dementia, such as a music intervention or other types of exercises (Cheung, Ho, Chan, et al. 2022; Cheung, Lai, et al. 2020; Efendi et al. 2023). The lasting effect of an exergame is another topic that may be of interest to stakeholders.

TABLE 2 | GRADE certainty of evidence.

Certainty assessment							No. of patients		Effect		
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Exergames	Control	Relative (95% CI)	Absolute (95% CI)	Certainty
4	Randomised trials	Serious[a]	Serious[b]	Not serious	Serious[c]	None	104	112	—	SMD 1.46 lower (2.5 lower to 0.43 lower)	⊕○○○ Very low[a], [bc]

[a]Most information is from studies at moderate risk of bias. Participants were aware of the arm to which they were allocated.
[b]The statistical test for heterogeneity shows low p value ($p < 0.00001$) and I^2 (91%) is large.
[c]The criterion for an optimal information size is not met.

5.4 | Implications for Practice

This systematic review might implicate future practice regarding exergaming. A beneficial effect of exergaming on depressive symptoms among PwD has been found in our review. This might provide evidence for healthcare professionals and informal caregivers to make an informed decision on exergaming as their anti-depressive intervention for PwD in different settings, such as hospital, residential facilities and communities and further explore the potential value. Moreover, findings from this review in terms of the contents, the interventionists and the training variables might inform designers and providers in the health game context of the direction of design and implementation of exergames.

5.5 | Implications for Research

Findings from this review have also indicated that exergame for depression is in its infancy and worth further research. As a moderate-to-severe risk of bias was found in the reviewed studies, mainly owing to loss to follow-up and absence of assessor blinding, it is also suggested performing studies with more rigorous methodologies, such as large sample size and blinding of assessors, in order to improve the validity of evidence. Furthermore, heterogeneity in contents and participants' characteristics was sought in our review. Our understanding of the moderation effects of various contents and participants' characteristics to exergaming might be greatly strengthened by subgroup analysis.

6 | Conclusions

Depressive symptoms are common among older adults with dementia. The findings of this review suggested that exergaming can produce a statistically significant improvement. Yet, a moderate-to-severe risk of bias was found owing to loss to follow-up and the absence of assessor blinding. Therefore, it is recommended that a rigorous study be conducted in the future. This study provides evidence for healthcare professionals and informal caregivers to use exergames to address depressive symptoms among older PWD.

Author Contributions

Conceptualisation, data extraction and study screening: D.S.K.C, H.Y.J.T., C.Y.C., W.L.W., K.K.C., S.W.L., L.L.L., T.Y.W. and Y.K.S. Meta-analysis and interpretation: D.S.K.C, H.Y.J.T., D.W.-C.W. Revision: D.W.-C.W. and H.Y.J.T. All authors contributed to the methodology, writing – original draft preparation.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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Supporting Information

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