

The Effectiveness of Exergaming Interventions for Depressive Symptoms and Quality of Life in Old Patients with Dementia: A Systematic Review and Meta-analysis

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The Effectiveness of Exergaming Interventions for Depressive Symptoms and Quality of Life in Old Patients with Dementia: A Systematic Review and Meta-analysis

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Abstract

Background: Exergame, a novel and promising combination of exercise and video games, has been suggested by previous studies to have an association with depression and quality of life. However, it is evidenced that the effectiveness regarding of depressive symptoms and quality of life in older patients with dementia(OPwD) remain mixed.

Objective: This systematic review and meta-analysis aimed to quantify the effects of intervening with exergames on depressive symptoms and quality of life in OPwD.

Methods: A comprehensive search of 5 electronic databases was conducted for randomized controlled trials published in English and Chinese from the establishment of the databases to December 1,2024. Eligible studies used exergaming interventions to reduce depression and quality of life in OPwD. In total, 2 independent reviewers screened the retrieved records, extracted data, and evaluated the risk of bias using the Revised Cochrane risk-of-bias tool. Discrepancies were resolved by a third reviewer. Meta-analysis and systematic review were performed using Review Manager 5.4 and Stata 16.0.

Setting: Included databases were Web of Science(WoS), PubMed, China National Knowledge Infrastructure(CNKI),WanFang Data(WFD), and VIP Information Databases, searched from the establishment of the databases to December 1, 2024.

Results: In total, 9 randomized controlled trials (n=494) were screened and included. (1) In terms of improving depressive symptoms, disregarding 1 study that resulted in heterogeneity, the meta-analysis of 5 studies revealed that exergames could significantly alleviate depressive symptoms in OPwD [SMD=?0.97, 95%CI (?1.24 to ?0.71), P<0.00001]. Subgroup analysis showed that changes in the number of intervention cycle and intervention frequency had a significant impact in the intervention effect. (2) In terms of improving quality of life, meta-analysis of 6 studies showed that exergames significantly improved the quality of life of older patients [SMD=0.75, 95% CI (0.50 to 1.00), P<0.00001], with a very low heterogeneity level(I²=0%); subgroup analysis showed that the number of intervention weeks, intervention frequency, and intervention method had no significant impact on the effectiveness in improving quality of life.

Conclusions: Exergaming intervention shows potential in reducing depressive symptoms and enhancing quality of life (QoL) in older persons with dementia (OPwD). While intervention frequency influences outcomes, QoL improvements appear consistent across variations in cycle, duration, and delivery method. Further research with larger samples and rigorous designs is needed to confirm both short- and long-term benefits and clarify the mechanisms behind specific exergaming protocols. Clinical Trial: The methods were preregistered with PROSPERO (International Prospective Register of Systematic Reviews, registration number CRD420251032107, registration on April 14, 2025).

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Original Manuscript

The Effectiveness of Exergaming Interventions for Depressive Symptoms and Quality of Life in Old Patients with Dementia: A Systematic Review and Meta-analysis

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Abstract

Background: Exergame, a novel and promising combination of exercise and video games, has been suggested by previous studies to have an association with depression and quality of life. However, it is evidenced that the effectiveness regarding of depressive symptoms and quality of life in older patients with dementia(OPwD) remain mixed.

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Conclusions: Exergaming intervention shows potential in reducing depressive symptoms and enhancing quality of life (QoL) in older persons with dementia (OPwD). While intervention frequency influences outcomes, QoL improvements appear consistent across variations in cycle, duration, and delivery method. Further research with larger samples and rigorous designs is needed to confirm both short- and long-term benefits and clarify the mechanisms behind specific exergaming protocols.

Keywords: older adults; dementia; exergaming interventions; depression; quality of life; meta-analysis; systematic review

Introduction

Dementia, a progressive neurocognitive disorder, is one of the main causes of disability and incapacity in the older adult population [1]. The number of older patients affected by dementia worldwide is continuously on the rise, with 55.2 million reported older patients as of 2019 [2], and an estimated count of 82 million in 2030 [3]. Amidst these older patients, 15.9~41% have reported suffering from depressive symptoms [4,5]. According to an epidemiological survey conducted in China from 2018 to 2022, as high as 20.6% of the older adult population was observed to display symptoms of depression [6]. Depression in older adults is predominantly a result of factors including physical deterioration, cognitive decline [7,8], co-occurrence of multiple medical conditions (comorbidity) and increased inflammatory risk [9,10], insufficient psychological counseling and decreased social relations [9-14]. Depression affects an individual's mental state, interpersonal relationships, and dependency on others, thereby reducing quality of life (QoL) of older adults in communities and nursing hospitals [15-18].

Previous studies have shown that physical activity has a significant negative correlation to severity of depressive symptoms [19]. The World Health Organization guidelines on physical activity recommended that older adults engage in at least 150~300 minutes of moderate-intensity physical activity (PA) per week, 75~150 minutes of vigorous-intensity physical activity per week or an equivalent combination of both [20]. Besides, a moderate increase in the amount of exercise can reduce the risk of depression in an older patient [21]. Exercise reduces the risk of depression by regulating monoamine neurotransmitters and reducing comorbidities [22-24]. In China, traditional Tai Chi and dance programs were modified to reduce depressive symptoms through endorphin mechanisms [25,26], and participation in community-based physical activity programs reduce the risk of depression by promoting social and physical interaction [27,28]. In addition, studies have further shown that physical activity and exercise are core components of older adults' health services for community older adults and residential caregivers [29], and are key to improving their QoL [30,31]. Specifically, regular aerobic exercise and resistance training can also help to improve cardiopulmonary and muscular strength and flexibility, further improving their quality of life [32-36]. Through tailored PA for older adults, we can effectively facilitate the restoration of physical and mental health and improve the quality of life of OPwD [37].

Inadequate physical activity demonstrates a significant association with heightened dementia risk in susceptible populations, with 66.6% of individuals mainly engaging in only low-intensity activities, and a majority of the group failing to meet recommended PA levels by the World Health Organization's guidelines [38]. One of every fifteen cases of dementia can be attributed to lack of physical activity [39]. OPwD often report disorientation, negative attitudes toward exercise or lack of behavioral control [40], emotional apathy [41], reduced initiative and diminished interest. In response, there is a growing call to shift the focus of PA from its health-promotion utility to emphasizing the personal experience [42]. Since self emotional feeling in PA participation may

provide an effective strategy to enhance PA adherence in terms of mood rewarding which plays an essential role in driving behavior [43]. Although studies have confirmed that somatosensory games have significant positive effects on people with neurocognitive disorders on physiological [44,45] and psychological levels [46,47], exercise or physical activity is often overlooked in day care centers or home-nursing cases [48]. Exergaming, a fusion of “exercise” and “games”, are interactive video games that combine physical activity with digital engagement using motion-sensing technologies to track and respond to players’ movements in real time [49,50]. Exergaming may integrate physical exercise within VR environments spanning non-immersive (standard screens with motion-sensor), semi-immersive (projection systems), and fully immersive (head-mounted displays with motion tracking) configurations [51]. Through using player movement tracking as a game mechanism, it achieves the dual goals of promoting physical exercise and cognitive stimulation [52,53], playing a unique role in promoting healthy aging and delaying cognitive decline [54,55]. Many studies have demonstrated that exergames not only prevent falls in older adults at various levels of physical health [56], there is also discussion on its effectiveness in fatigue reduction among cancer related children cases [57], thus improving quality of life.

Although one previous review prior to 2018 have explored effects of exergaming to depression in people with dementia [58], no subsequent synthesis has been conducted since 2019. Notably, 7 out of 9 our included studies were published within the past five years, highlighting the rapidly evolving evidence. Importantly, the specific effects of exergaming on depressive symptoms and quality of life among OPwD remain underexamined in systematic reviews. A rigorous, up-to-date systematic review targeting this gap is therefore imperative. Thus, by focusing on the effects of exergaming interventions on depressive symptoms and quality of life(QoL) of OPwD, this systematic review and meta-analysis aim address key research gaps by (1) assessing the impact of exergaming interventions on depression and QoL in OPwD, (2) revealing the replicability of exergaming intervention studies and necessity of high-quality RCTs; (3) recognizing the most effective design element in exergaming interventions effects on depression and QoL improvement in OPwD.

Methodology

This review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 statement [59]. The methods were preregistered with PROSPERO (International Prospective Register of Systematic Reviews, registration number CRD420251032107, registration on April 14, 2025).

Eligibility Criteria

Eligible studies met the following criteria:

- 1.Participants: Older patients aged 60 years or older with a diagnosis of any type of dementia, such as major neurocognitive disorder, Alzheimer’s disease etc..
- 2.Interventions: Included studies focused on exergaming interventions delivered by active virtual games or somatosensory games with Kinect, Wii-Fit etc., aiming to reduce depressive symptoms and quality of life.
- 3.Comparators: When available, control groups were included for between-group comparisons using meta-analysis.
- 4.Outcomes: Studies assessing results and findings in terms of depressive symptoms or quality of life or both were included. These outcomes were required to be obtained by international standardized scales by device-based measurements or self-report.
- 5.Study designs: Only randomized controlled trials(RCTs) were eligible.
- 6.Publication status: Full-text research papers were eligible, while conference proceedings,

dissertations, and grey literature were excluded.

7. Language: English-language and Chinese-language studies were included.

Information Sources

This study employed to search for literature related to exergames/AVGs, depressive symptoms and quality of life in OPwD is to combine subject terms and free terms from 5 electronic databases, including Web of Science (WoS), PubMed, WanFang Data, CNCK, and VIP Information Databases. The search period was from the establishment of the databases to December 2024. To ensure comprehensive coverage, we manually screened reference lists and studies included in relevant systematic reviews and meta-analyses for additional eligible studies.

Search Strategy

The search strategy, informed by previous systematic reviews [60], targeted 5 key topics: older adults, dementia, exergames, depression, and quality of life. It was initially formulated for Web of Science and subsequently adapted for use in the other databases.

Selection Process

The search results were imported into EndNote for comprehensive reference management. Following initial automated deduplication, manual verification was performed to ensure complete removal of duplicate records. Two independent reviewers (Wenxuan L and Ling S) conducted a rigorous three-phase screening process, sequentially evaluating titles, abstracts, and full-text articles to identify studies meeting the predefined eligibility criteria. To maintain methodological rigor, any discrepancies in study selection were adjudicated through consultation with a senior reviewer (Bing Z) until consensus was achieved.

Data Extraction

Two independent reviewers (Wenxuan L and Ling S) performed initial data extraction and cross-verification, with discrepancies resolved through arbitration by a third researcher (Bing Z). Extracted data were systematically cataloged in predefined Microsoft Excel spreadsheets, including: Study characteristics (first author, publication year, country of origin, and language); Participant demographics (sample size, age distribution, sex/gender, and diagnostic criteria); Outcome measures (assessment scales, methodological approaches, and longitudinal data). Intervention protocols were comprehensively characterized using the Template for Intervention Description and Replication (TIDieR) checklist [61], covering aspects such as Why (rationale/theoretical framework), What (content, procedures, and materials/exergaming intervention means), Who provided (personnel/intervention provider), How (mode of intervention), Where (location), When and How much (duration and frequency), Tailoring (adaptation/individualized items), and How well (adherence and attrition).

Risk of Bias

The methodological quality and risk of bias were rigorously evaluated using the Revised Cochrane Risk of Bias tool for randomized trials (RoB 2) [62]. This validated instrument systematically assesses five critical domains: (1) randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) outcome measurement, and (5) selective reporting of results. To ensure reliability, two independent reviewers (Wenxuan L and Ling S) conducted parallel assessments. Any inconsistencies in bias evaluation were resolved through consensus discussions.

with a senior reviewer (Bing Z) to reach final determinations.

Statistical analysis

The characteristics and TIDieR results were narratively synthesized, with frequency counts and percentages presented in tables. This qualitative synthesis incorporated all eligible studies, including those where quantitative data extraction was not obtained. **Statistical analyses were conducted using Review Manager 5.4 and Stata 16.0.** The outcome indicators of the 9 included randomized controlled trials were continuous variables with inconsistent dimensions, so the standardized mean difference (SMD) and its 95% confidence interval (CI) were used as the combined effect level indicators [63]. In the heterogeneity test, with a low heterogeneity level, as indicated by a test result of $I^2 < 50\%$ and $P > 0.100$, the fixed effect model was applied to derive the pooled effect estimate by calculating the inverse-variance-weighted average of individual study effects; otherwise, the random effect model was selected to explore the source of heterogeneity and conduct subgroup analysis [64].

Certainty Assessment

We assessed the quality of the evidence using the web-based version GRADEpro GDT (Grading of Recommendations Assessment, Development and Evaluation professional guideline development tool). Although RCT evidence typically starts at a high-quality rating, we evaluated the following domains to determine any necessary downgrades: (1) risk of bias, (2) inconsistency, (3) indirectness, (4) imprecision, and (5) publication bias [65].

Results

Study Selection

The detailed search strategies for each database are provided in Table S1 in Multimedia Appendix 1. The study screening process was completed independently by two reviewers, and any disagreements were discussed and resolved with a third reviewer. The initial search yielded 2297 records (1935 in English and 362 in Chinese), and 537 duplicate studies were removed, leaving 1760 studies; 1470 studies were filtered after reading the respective titles and abstracts, leaving 189 full text studies were eligible assessed. Additionally, 82 records were identified in relevant systematic reviews. After removing duplicates and screening titles and abstracts, 14 full-text papers left. In total, 9 studies remained and were included in the narrative synthesis. During the process of screening the titles and abstracts, Cohen's kappa consistency between the raters was 0.92, and when screening the full texts, it was 0.95. The study selection process is illustrated in Figure 1.

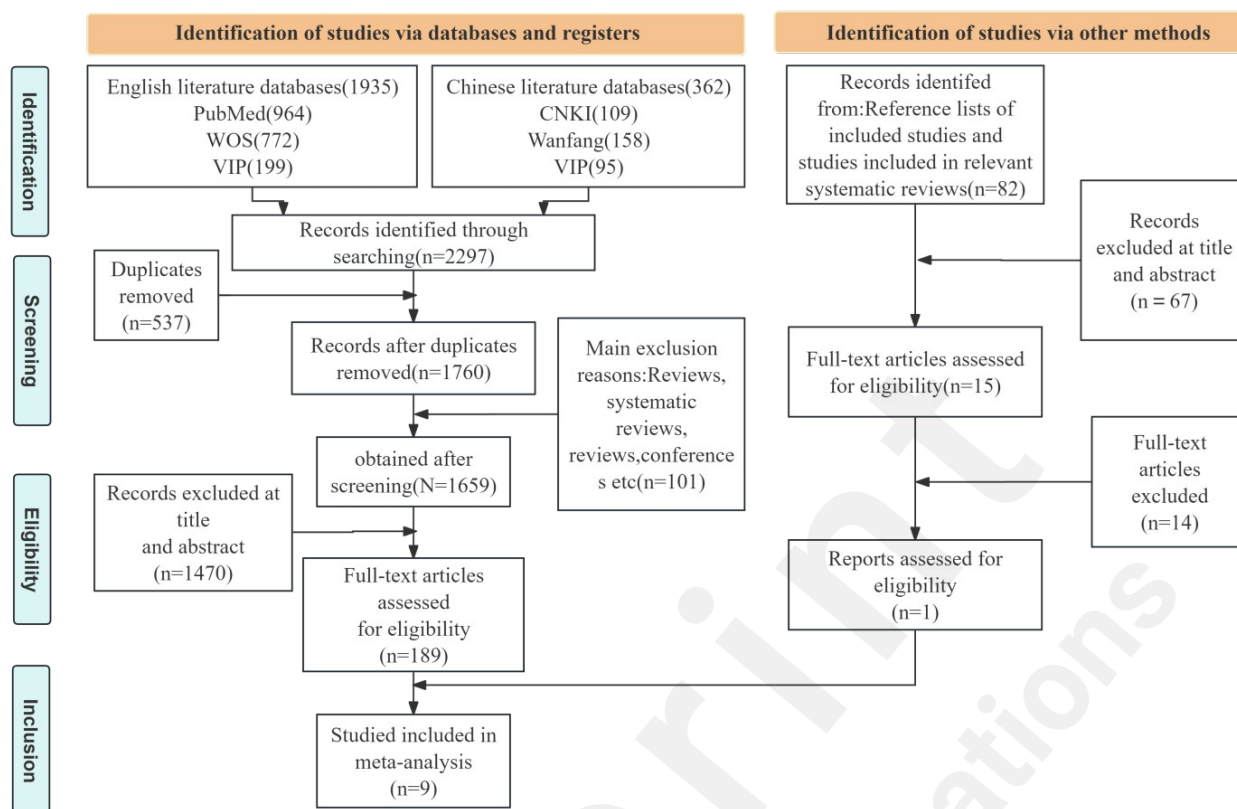


Figure 1. Flowchart for study identification, screening, eligibility, and inclusion

Study Characteristics

Overview

Table S2 in Multimedia Appendix summarizes the characteristics of the included studies. A total of 9 studies were included in this study, published from the establishment of the database to 2024, and the number of studies showed an increasing trend over time. The study in 2013 broke through the traditional single-treatment model and adopted an intervention combining physical activity and cognitive training to explore its impact on the mental health of dementia patients [66]. 6 studies from 2020 to the present also used the same intervention method combining physical activity and cognitive training. The cumulative sample size of the included studies was 488, with the sample size ranging from 20 to 90. Only 1 study had a sample size of ≥ 90 , 4 studies had a sample size between 89 to 50, and the remaining studies had a sample size of < 50 . The 9 studies included in this paper involved 4 countries, with 6 from China, and the other 3 from the United States(US) [67], Republic of Korea(RoK) [66], and Belgium respectively [45].

Intervention Characteristics According to the TIDieR Checklist

The TIDieR framework serves as a robust methodological tool to empirically assess the adherence to reporting standards normativity, feasibility of implementation, and replicability of intervention studies [61]. The intervention characteristics are summarized in Table 4, including 5 key aspects of theoretical rationale (Why), Modality (How), Duration and frequency (How long), Tailoring, and Adherence and Attrition in Implementation (How well). Additional details regarding intervention components (What) are outlined in the following section, with comprehensive documentation provided in Table S4 in Multimedia Appendix.

Rationale (Why)

None of the studies applied theoretical framework to guide their interventions. But, all had previous evidences from similar studies and reasons why the studies were used.

Intervention content (What)

The research goals and protocols were used in all included studies. All included studies incorporated materials or devices for exergaming interventions like Wii-Fit program [67], MULT TASK software system [68], Kinet game Fruit Ninja [69,70], cognitive training and cycling exercise [66], HTC VIVE Pro Head-Mounted Display [71], Dividat Senso exergame device [45], Hailan VR Rehabilitation Digital Assessment System(HVR-RDAS) [72], and Nanjing Motion MoXun TechV2.0(NMMT) [73]. Detailed descriptions of interventions are provided in Table S5 in Multimedia Appendix.

Mode of Intervention (How)

Applications were most commonly used delivery method, with 4 studies using widespread commercial applications to deliver game interventions [67,69-71]. In total, 1 study used Chinese independently designed and developed cognitive training systems [72]. 3 studies used software and platforms [45,68,73]. Additionally, Xie compared the effectiveness of immersive VR games such as Ninja fruit to the non-immersive games on iPad [71]. 1 study provided combined cognitive training and cycling exercise to test effectiveness among OPwD.

Intervention Duration (When and How Much)

The intervention periods ranged from 1 month [68,72] to 6 months [73]. Two was more than 8 weeks, More than two-third of the interventions(n=7) were 8 weeks, two was short (4 weeks). In total, 1 study included predefined follow-up periods ranging from 2 months to 4 months [67].

Adherence and Attrition (How Well)

In total, the average dropout rate is 21.9%. Attrition rates of 3 studies were low with reported low dropout rates (< 22%) [45,67,69]. Most of Chinese published studies did not report the dropout rate [68,70-73]. Besides, 1 study reported a high dropout rate (>23%) [66]. Intervention adherence was evaluated through task completion and scales assessment.

TIDieR Coding

The completeness of reporting across TIDieR items varied, ranging from 58.3% (n=2) [68] to 100% (n=1) [45], with an average of 72.2% items adequately reported. The most consistently reported items were why (item 2), what (item 3 and 4), how (item 6) and when (item 8), how well (item 9) of interventions. And the descriptions of locations of intervention were all covered but 1 study lack clarity (item 7) [68]. In total, 4 studies tailored patients' intervention modes on baseline data (item 9) [45,67,73] and modified interventions parameters. Similarly, just one study explicitly stated that the intervention was implemented in government-run day care center and a nursing home of local community [69]. Adherence or fidelity (item 12) was reported in all studies. A detailed summary of TIDieR items' completeness is presented in Table S3 in Multimedia Appendix.

Literature quality evaluation was independently conducted by two reviewers. Quality evaluation of the included randomized controlled trial (RCT) studies was assessed using the Revised Cochrane risk-of-bias tool [74]. The bias risk of studies was divided into three grades: if five or more items presented low risk, it was determined as low bias risk; if three to items were of low risk, it was classified as four moderate bias risk; if the number of low-risk items was less than three, it was categorized as high bias risk [75]. Among all included articles, 7 studies had low bias risk [45,68-73], and 2 studies had moderate bias risk [66,67]. Finally, the quality information of the included studies was imported into Review Manager 5.4 software to draw the bias risk graphs in Figure S1 in Multimedia Appendix.

Outcome characteristics

In total, 3 studies focused on depression, assessed with scales of HAMD [71,72] and CSDD [70]; 3 studies focused on QoL with scales of QoL-AD [67,68,73]. Beside, in the 3 studies focusing the 2 variables at the same time, apart from 1 study used GDS to assess depression and GDS, KSCE,

and MMSE-K to assess QoL [66], the other 2 scales of CSDD and QoL-AD were used in assessment of depression and QoL respectively [45,69]. Among all the included studies, 1 study has reported 8-wk and follow-up 8-wk test's outcomes [67].

Results of Syntheses

Before formally constructing data charts, the research team first listed the key takeaways of the project according to its research purpose, and then randomly selected 5 to 10 targeted studies with respect to the total number of included articles according to the criteria proposed by Colquhoun et al. [76] to confirm the content to be clearly displayed by the data charts.

Depressive Symptoms

A total of 6 randomized controlled trials (RCTs) evaluated the alleviation of depressive symptoms in dementia patients through exergaming interventions. Heterogeneity analysis revealed an I^2 value of 87%, indicating high heterogeneity. Hence, the random effects model was used for effect size combination. The meta-analysis results revealed a standardized mean difference (SMD) of -1.25 (95% CI -1.94 to -0.55 , $P < 0.00001$), with statistically significant differences, indicating that the intervention group performed better than the control group in the corresponding indicators (Figure S2 in Multimedia Appendix).

A funnel plot was constructed to assess publication bias regarding the effect of depressive symptom improvement [77]. The results demonstrated approximate symmetry in the distribution of study points in the Figure S3 in Multimedia Appendix. In conjunction with Egger's test ($p = 0.2654$), these findings suggest no significant risk of publication bias.

To explore whether the heterogeneity was induced by a single study, sensitivity analysis was performed using Stata version 16.0. When excluding studies one by one, the effect size estimates remained within the 95% confidence interval (CI) of the original effect size after removing most studies, indicating good stability of the results. However, after excluding the study by Zhu [70], the effect size estimate exceeded the 95% CI of the original effect size, suggesting that this study affected the result stability, see Figure S4 in Multimedia Appendix.

After excluding the study that affected the result stability, meta-analysis was performed again. The results showed an I^2 value of 42%, indicating moderate heterogeneity, so a random-effects model was used to combine effect sizes. The meta-analysis results showed a standardized mean difference (SMD) of -0.97 (95% CI: -1.24 to -0.71 , $P < 0.00001$), with statistically significant differences, suggesting that the exergaming group performed better than the routine care group in the corresponding indicators (Figure 3).

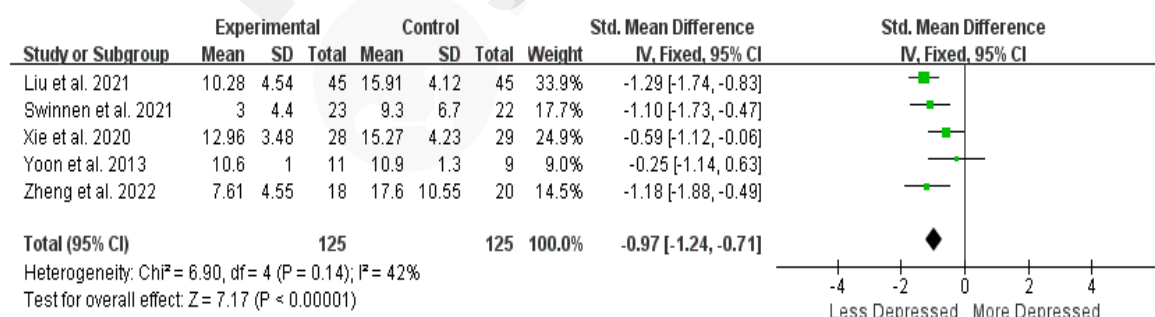


Figure 3. Forest plots of the effect to depression of all included studies excluding Zhu et al.

To further explore the sources of heterogeneity, subgroup analyses were conducted on intervention cycle (weeks), intervention frequencies, intervention methods, and scale types that might contribute to heterogeneity. Subgroup analyses were performed on the 5 studies after excluding the article that

caused heterogeneity. The intervention cycle in the included studies ranged from 4 to 16 weeks, with a mean of 8.8 weeks. Thus, studies with an intervention cycle >8 weeks were defined as the long duration intervention group, and those ≤ 8 weeks were classified as the short duration intervention group. The intervention frequency ranged from 2 to 5 times per week, with a mean of 3.6 times per week. Therefore, studies with an intervention frequency >4 times per week were defined as the high-frequency group, and those ≤ 4 times per week were classified as the low-frequency group. Among the 5 included studies, 3 used exergaming and 2 used virtual reality (VR) as interventions. Thus, intervention methods were divided into the exergaming group and the VR group in the subgroup analysis. Depression symptom measurement scales were categorized into the Cornell Scale for Depression in Dementia (CSDD group), Geriatric Depression Scale (GDS group), and Hamilton Depression Rating Scale (HAMD group), based on which subgroup analyses were performed, see Table 3.

Table 3. Subgroup analysis for depressive symptoms of OPwD

Subgroup type	Heterogeneity (I^2 , P)	Cohen d (95% CI)	Weight (%)	Test for overall effect (P value)
Intervention cycle (wk)				0.011
≤ 8	$I^2=0.0\%, P=0.898$	$-1.23(-1.56 \text{ to } -0.90)$	66.11	
> 8	$I^2=0.0\%, P=0.527$	$-0.51(-0.96 \text{ to } -0.05)$	33.89	
Intervention frequency(times/wk)				0.040
> 4	$I^2=0.00\%, P=0.829$	$-1.27(-1.65 \text{ to } -0.89)$	48.41	
≤ 4	$I^2=27.5\%, P=0.252$	$-0.72(-1.09 \text{ to } -0.35)$	51.59	
Intervention method				0.890
Exergaming group	$I^2=35.6\%, P=0.211$	$-0.96(-1.38 \text{ to } -0.55)$	41.21	
VR group	$I^2=74.2\%, P=0.049$	$-1.00(-1.35 \text{ to } -0.65)$	58.79	
Scale type				0.213
CSDD	$I^2=0.0\%, P=0.851$	$-1.16(-1.62 \text{ to } -0.69)$	32.24	
GDS	NA	$-0.26(-1.15 \text{ to } 0.62)$	8.97	
HAMD	$I^2=74.2\%, P=0.049$	$-1.00(-1.35 \text{ to } -0.65)$	58.79	

Abbreviation: VR, Virtual Reality; GDS, Geriatric Depression Scale; CSDD, Cornell Scale for Depression in Dementia; HAMD, Hamilton Depression Rating Scale

Subgroup analysis by intervention cycle revealed significant between-group heterogeneity ($P = 0.011$), indicating differential treatment effects across weeks. Longer duration group (>8 weeks) showed no heterogeneity ($I^2 = 0.0\%$, $P = 0.898$) with a large, statistically significant effect (SMD = -1.23 , 95% CI: -1.56 to -0.90), accounting for 66.11% of weight in the analysis. In contrast, Shorter duration group (≤ 8 weeks) also demonstrated no heterogeneity ($I^2 = 0.0\%$, $P = 0.527$) but yielded a smaller yet still significant effect (SMD = -0.51 , 95% CI: -0.96 to -0.05), contributing 33.89%

weight. These findings suggest that intervention duration significantly moderates treatment efficacy, with extended interventions producing substantially greater benefits for the target outcome. The consistent absence of within-subgroup heterogeneity ($I^2 = 0.0\%$ in both cases) strengthens the reliability of these duration-dependent effects.

The intervention frequency had a significant impact on the intervention effect. In the subgroup analysis of intervention frequency, the heterogeneity test across subgroups showed a P -value of 0.040, indicating a significant difference in the impact of different intervention frequency on the intervention effect. The high-frequency group (>4 times/wk) showed no heterogeneity ($I^2 = 0.00\%$, $P = 0.829$), (SMD = -1.27 , 95%CI: -1.65 to -0.89), accounting for 48.41% of weight in the analysis. While the low-frequency group (≤ 4 times/wk) demonstrated low heterogeneity ($I^2 = 27.5\%$, $P = 0.252$) but yielded a smaller yet still significant effect (SMD = -0.72 , 95%CI: -1.09 to -0.35), contributing 51.59% weight.

The intervention methods showed no significant effect on outcomes (subgroup $P=0.890$).

Exergaming had low heterogeneity ($I^2=35.6\%$, $P=0.211$; SMD= -0.96 to -1.38 to -0.55 ; weight=41.21%), while VR showed high heterogeneity ($I^2=74.2\%$, $P=0.049$; SMD= -1.00 , 95%CI: -1.35 to -0.65 ; weight=58.79%).

Similarly, scale types had no significant impact (subgroup $P=0.213$). CSDD showed no heterogeneity ($I^2=0.0\%$, $P=0.851$; SMD= -1.16 , -1.62 to -0.69 ; weight = 32.24%), while HAMD had high heterogeneity ($I^2=74.2\%$, $P=0.049$; SMD= -1.00 , 95%CI: -1.35 to -0.65 ; weight=58.79%).

Quality of Life

A total of 6 randomized controlled trials evaluated the quality of life in OPwD. Heterogeneity analysis revealed an I^2 value of 0%, indicating no heterogeneity. Hence, the fixed effects model was used for effect size combination. The results showed that exergaming could improve the quality of life of patients, and the difference was statistically significant (SMD=0.75, 95%CI (0.50 to 1.00), $P < 0.00001$) (Figure 4).

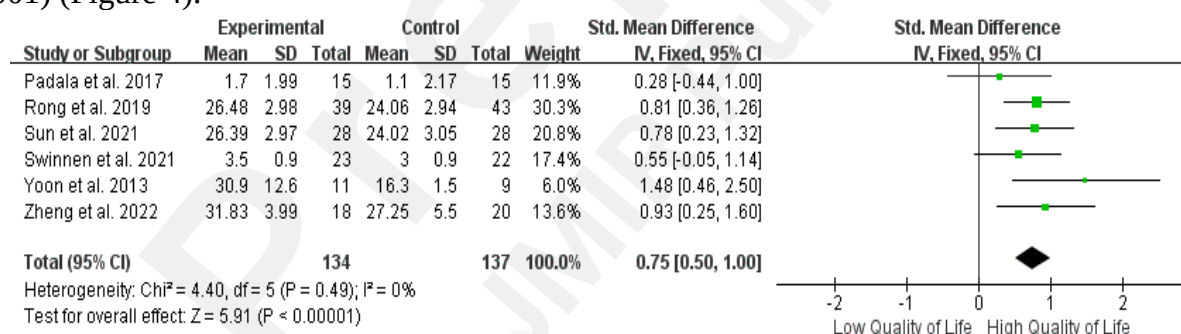


Figure 4. Forest plot of the effect of exergaming to quality of life

To evaluate potential publication bias in quality of life improvement outcomes, a funnel plot was analyzed. The plot demonstrated approximate symmetry (Figure S5 in Multimedia Appendix). Combined with Egger's test ($P = 0.5390$), these findings suggest no significant risk of publication bias.

Among the 6 included studies, 3 had an intervention cycle of 8 weeks, 1 had 4 weeks, one had 12 weeks, and 1 had 24 weeks. Therefore, in the subgroup analysis, intervention cycle were divided into short (≤ 8 wks) and long (> 8 wks) groups. Three studies had an intervention frequency of 3 times per week, two had 5 times per week, and one had 7 times per week. Thus, the subgroup analysis categorized intervention frequencies as a low-frequency group (≤ 3 times per wk) and a high-frequency group (> 3 times per wk). Additionally, 4 of the 6 studies used exergaming as the intervention method, while 2 studies used VR. Therefore, intervention methods were divided into exergaming group and VR group, see Table 4.

Table 4. Subgroup analysis for quality of life of OPwD

Subgroup type	Heterogeneity (I^2 , P)	Cohen d (95% CI)	Weight (%)	Test for overall effect (P value)
Intervention cycle (wk)				0.357
≤ 8	$I^2=0.0\%, P=0.52$ 2	0.69 (0.40–0.98)	73.19	
> 8	$I^2=39.9\%, P=0.1$ 97	0.88 (0.48–1.44)	26.81	
Intervention frequency(times/wk)				0.804
> 3	$I^2=0.0\%, P=0.37$ 1	0.74 (0.40 to 1.07)	55.82	
≤ 3	$I^2=26.5\%, P=0.2$ 57	0.80 (0.43 to 1.17)	44.18	
Intervention method				0.737
Exergaming group	$I^2=35.4\%, P=0.2$ 00	0.72 (0.36 to 1.08)	48.90	
VR group	$I^2=0.0\%, P=0.93$ 3	0.81 (0.46 to 1.15)	51.10	

Abbreviation: VR, Virtual Reality.

The intervention cycle had no significant impact on the intervention effect. The heterogeneity test across subgroups showed a P -value of 0.357, indicating no significant difference in the impact of different intervention cycle on the intervention effect. Short duration group showed no heterogeneity ($I^2=0.0\%$, $P=0.522$), (SMD=0.69, 95%CI: 0.40 to 0.98), accounting for 73.19% of weight in the analysis. Long duration group demonstrated no heterogeneity ($I^2=39.9\%$, $P=0.197$), (SMD=0.88, 95%CI: 0.48 to 1.44), contributing 26.81% weight.

The intervention frequency had no significant impact on the intervention effect. The heterogeneity test across subgroups showed a P -value of 0.804, indicating no significant difference in the impact of different intervention frequency on the intervention effect. The high frequency group showed no heterogeneity ($I^2=0.0\%$, $P=0.371$), (SMD=0.74, 95%CI: 0.40 to 1.07), accounting for 55.82% of weight in the analysis. The low frequency group demonstrated low heterogeneity ($I^2=26.5\%$, $P=0.257$), (SMD=0.80, 95%CI: 0.43 to 1.17), contributing 44.18% weight. Besides, the intervention methods had no significant impact on the intervention effect. The heterogeneity test across subgroups showed a P -value of 0.737, indicating no significant difference in the impact of different intervention methods on the intervention effect. VR group showed low heterogeneity ($I^2=35.4\%$, $P=0.200$) while exergaming group demonstrated no heterogeneity ($I^2=0.00\%$, $P=0.933$).

Certainty Assessment

After conducting the sensitivity analysis, the quality of evidence for depression and QoL were rated as high (see Table S7 in Multimedia Appendix 1).

Discussion

This study systematically reviewed and meta-analyzed 9 randomized controlled trials (n=616) to analyze the effects of exergaming intervention on depression symptoms and quality of life in OPwD. The main conclusion is that (1) exergaming interventions could significantly alleviate older patients' depressive symptoms [SMD=-0.97, 95%CI (-1.24 to -0.71), $P<0.00001$], (2) and had a positive effect on quality of life [SMD=0.75, 95%CI (0.50 to 1.00), $P<0.00001$], (3) the intervention cycle and frequency were significant factors affecting the improvement of depressive symptoms, while the improvement of quality of life remained stable under different weekly interventions, frequencies and methods respectively.

Firstly, the results of this study show that, in comparison with the control group, exergaming interventions can improve the depressive symptoms of OPwD, which is consistent with previous studies in adolescents, and both healthy and sick older adults, including AD older adults [78-80]. The intervention's efficacy may arise from its 3 dimensional mechanisms: Physiologically, aging-related decline and comorbidities increase depression risk [81], particularly through elevated inflammation [82]. Exergaming shares exercise's benefits in neurotransmitter modulation and inflammation reduction [22,23,24], while potentially alleviating depression via motor cortex activation [44,45]. Psychologically, exergaming counters dementia-related self-esteem loss [9-11] through endorphin-mediated mood improvement [25,26]. Socially, it addresses isolation-induced depression [83] by incorporating VR-based interactions [84] and group-based physical activities in community settings [85-87], disrupting the social deprivation-depression cycle [88].

In all included studies, it is observed that the variation in the intervention weeks and frequency has an impact on the extent of relief of depressive symptoms in OPwD. Short-term intervention is more effective than long-duration intervention, which may be due to the short-term reinforcement effect since long-duration delivery is likely to cause the older adults to adapt or develop tolerance, thus weakening the effect [89]. Similarly, the reason why higher frequency intervention is more effective may be that high-frequency intervention can more continuously strengthen the effect and maintain the responsiveness of the participants, and promote more obvious changes [90]. In contrast, the difference in intervention method and measurement scales did not significantly affect the improvement of depressive symptoms in OPwD. This may be because the intervention methods are homogeneous and undistinguishable. Besides, the most of the selected scales may have substantially overlapping dimensions, and the precision and accuracy levels are comparable, with consistent sensitivity to research results in depressive assessment.

Secondly, consistent with most previous studies, exergaming has been demonstrated to enhance quality of life (QoL) in adolescents, healthy older adults, and elderly patients with various conditions [45,91]. However, diverging from the systematic review published in 2023 which reported no significant QoL improvement [47], the current analysis suggests this discrepancy may stem from two methodological limitations: (1) exclusive inclusion of English-language literature potentially omitting critical evidence from Asian populations, and (2) conflation of dementia and mild cognitive impairment (MCI) cases despite their distinct pathological mechanisms and disease progression stages. Our study employed a more comprehensive search strategy encompassing both international databases (WoS and PubMed) and three major Chinese databases (CNKI, WanFang, and VIP), thereby capturing culturally diverse evidence and constructing a more robust body of literature. Thematically, we specifically focused on dementia populations, eliminating confounding effects from varying disease stages and enabling precise evaluation of exergaming interventions for individuals with moderate-to-severe cognitive impairment.

We found that the variation in exergaming intervention weeks, frequency, and methods had no significant effect on the quality of life of OPwD. This may be because QoL is a multidimensional concept, which is affected by multiple factors including physiological, psychological, and social aspects thus its improvement process often presents as asynchronous and nonlinear. Specifically, physiological functional improvement (such as muscular strength and ability to balance) may require long-term intervention to produce a cumulative effect [92], while psychological or emotional improvement (such as anxiety relief and self-efficacy enhancement) may be more sensitive to constant high-frequency interaction [93-96], producing a more immediate result. Differences in technical materials used in interventions also lead to different results. Virtual reality games may stimulate cognitive reconstruction through immersive scenes, while somatosensory games are more likely to promote social interaction through physical movement [97]. These scattered positive effects complement and overlap in the multidimensional framework that measures quality of life. Therefore, although the difference in the intervention weeks, frequency, and methods has not reached a statistically significant level in terms of the impact on the QoL in OPwD, their combined effect still constitutes a key factor in improving the quality of life of older patients.

Limitations and Strengths

The limitations of our study are as follows. 1. Insufficient statistical power in nearly half of the studies. Over half of studies had small sample sizes (<50 participants), which might limit the ability to detect subgroup-specific effects of exergaming across different dementia subtypes (e.g., Alzheimer's disease vs. vascular dementia). 2. Substantial clinical heterogeneity. Variability was observed in the age range of participants (67.59~85.3 years), inconsistent classification of dementia severity, and intervention durations (ranging from 4 to 24 weeks). 3. Methodological heterogeneity. Some studies lacked rigorous implementation of allocation concealment and blinded outcome assessment. Furthermore, the absence of long-term follow-up data raises risks about the sustainability of the observed intervention effects.

The strengths of our study are as follows. 1. Adherence to rigorous methodological standards. This research strictly followed the PRISMA guidelines and comprehensively evaluated trial intervention process using the TIDieR checklist, ensuring transparency and reproducibility. 2. Broader evidence base. In contrast to prior studies (e.g., [47]), our analysis incorporated a larger number of both Chinese and international RCTs, enhancing the precision and generalizability of the conclusions. 3. Following comparative analysis principles, we examined key moderators (intervention cycle, frequency, mode of delivery, etc.) of exergaming's effects on depression and QoL in OPwD, establishing a theoretical framework for psychological intervention development for this specific group.

Conclusion

In conclusion, exergaming interventions display promise in alleviating depressive symptoms and improving quality of life. While the effects may differ in terms of the intervention frequency and cycle, especially for depressive symptoms of OPwD, the improvement of quality of life is not effected by the design element of cycle, duration, and method respectively. Due to the limited number of included studies, we were unable to fully delineate the single contributions of intervention elements despite subgroup analyses. Future research should employ larger sample sizes and standardized rigorous experimental designs to validate both the short- and long-term effectiveness of exergaming interventions on Depression and QoL, while further elucidating the mechanistic impacts of specific exergaming protocol designs on QoL.

Data Availability

All data generated or analyzed during this study are included in the supplementary files accompanying this published article.

Authors' Contributions

Bing Z was involved in conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft, writing-review and editing, project administration, and funding acquisition. Wenxuan L and Ling S was involved in validation, writing-original draft, software, formal analysis, resources, and visualization. Chan Sze W was involved in language refinement. Kaman L was involved in writing-review and editing, project administration, and funding acquisition.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Related multimedia appendix tables and figures.

Multimedia Appendix 2

PRISMA 2020 Checklist.

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Abbreviations

OPwD: old patient with dementia

AD: Alzheimer's disease

WHO: world health organization

QoL: quality of life

RCT: randomized controlled trial

SMD: standardized mean difference

CI: confidence interval

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

PROSPERO: International Prospective Register of Systematic Reviews

RoK: Republic of Korea

HVR-RDAS: Hailan VR Rehabilitation Digital Assessment System

NMNT; Nanjing Motion MoXun TechV2.0

MNCD, Major Neurocognitive disorder

MCI: mild cognitive impairment

KSCE, Kenny Self-Care Evaluation

GDS, Geriatric Depression Scale

CSDD, Cornell Scale for Depression in Dementia

HAMD, Hamilton Depression Rating Scale

QOL-AD, Quality of Life-Alzheimer's Disease

MMSE, Mini Mental Status Exam

MMSE-K, Mini Mental Status Exam-Korean version

Supplementary Files

Multimedia Appendixes

Tables and figures.

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