

# The Effectiveness of Exergame Exercises to Improve Cognitive Function in Cases of Dementia: Literature Review <sup>†</sup>

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**Abstract:** Dementia is a chronic and progressive condition where the sufferer experiences a decline in cognitive function. In 2016, cases of dementia in Indonesia reached 1.2 million cases and will increase because Indonesia is already in an aging population, so interventions are needed that can overcome problems in people with dementia, one of which is exergame. The effectiveness of giving exercise exergame to improve cognitive function in cases of dementia is known. From the search results of several databases, 35 articles were found, which were then filtered based on the inclusion–exclusion criteria so that 10 articles were obtained. Critical appraisal was carried out on 10 articles without duplication, and the final result after the selection was 5 articles. Of the five articles, three articles showed an increase in cognitive function after being given an exergame intervention from 8 weeks–6 months with a frequency of 3–5x/week. The exergame tools used in the three articles are Dividat Senso and interactive cycling. Exergame can be recommended as an intervention to improve cognitive function when used with the appropriate intervention dose, and the patient is obedient and disciplined in undergoing treatment.

**Keywords:** dementia; exergame; cognitive function; MMSE; MoCA



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## 1. Introduction

Dementia refers to a clinical syndrome characterized by a progressive cognitive decline that impairs the ability to function independently [1]. Dementia refers to a syndrome characterized by a progressive decline in cognitive function in individuals with neuropsychiatric symptoms such as apathy, agitation, and depression [2]. As the condition progresses, individuals gradually become dependent on others to perform daily activities.

Overall, about 55 million people have dementia, with the most common case being dementia due to Alzheimer’s, accounting for 60–70% of cases, with 60% coming from low to middle-income countries [3]. The predicted prevalence of men is 14 and 32 percent more than women in East Asia, South Asia, the Caribbean, Western Europe, and Latin America [4]. In Indonesia alone, there were around 1.2 million cases of dementia in 2016 [5].

One of the dominant functional disorders in dementia cases is cognitive function. Cognitive changes in people with dementia are problems with short-term memory, such as remembering what they wanted to do or say and remembering people’s names [6]. Problems that occur in other cognitive disorders are loss of initiative in taking action, difficulty in concentration, loss of language skills, agnosia, visual perception, and orientation to place and time. The disorder makes people with dementia complete daily activities or tasks for a longer time. As dementia progresses, sufferers gradually become more dependent on others to perform daily activities.

Currently, Indonesia has entered an aging population. The aging population is a condition where life expectancy (UHH) is increasing as a reflection of the success of one of the indicators of achieving national development, especially in the health sector [7]. This is

an indication of the increasing number of elderly people. The types of diseases that often occur in the elderly are non-communicable diseases, and dementia is one of them [8]. With the increase in the elderly population, the same will happen to the incidence of dementia.

Exergame is a combination of the words 'exercise' and 'gaming'. Exergaming means playing video games that require physical activity from the player [9]. Several types of exergames are used as interventions, such as interactive aerobic fitness games, motion capture technology games, dance simulation games, interactive cycling games, and isometric resistance games. Virtual reality also serves the purpose of being in line with exergames in that it allows the user to interact with a virtual experience using the user's body.

## 2. Research Methods

The research method used is a literature review. Search articles or journals using keywords and Boolean operators (AND, OR NOR, or AND NOT), which are used to expand or specify the search to make it easier to determine which publication to use. The search was conducted through PubMed, Science Direct, Scopus, Taylor and Francis, and Medline from December 2021 to February 2022, with inclusion and exclusion criteria as a filter.

The inclusion criteria for an article or journal for review are as follows: (1) men and women aged 50 years and over with a diagnosis of any type of dementia or major neurocognitive disorder (MNCD); (2) the intervention used was exergame; (3) researchers measured cognitive function, year of publication 2016–2022; (4) used English or Indonesian. An article was excluded if: (1) the patient suffers from mild cognitive impairment (mild cognitive impairment/MCI); (2) does not discuss search results cognitive function and not using exergame; (3) the publication year under 2016; (4) not using English or Indonesian; (5) research design in the form of expert opinion, systematic review, meta-analysis, and literature review. The strategies used to find articles using the PICO framework are population/problem is dementia, the intervention used is exergame, a comparison is not made, and the desired outcome is cognitive function.

## 3. Results

### 3.1. Study Selection

Based on the search results through the PubMed, Scopus, Science Direct, Taylor and Francis, and Medline databases using the keywords dementia OR Alzheimer's OR vascular dementia OR other dementia AND exergame OR exergaming OR exercise gaming OR virtual reality AND cognitive function, the researchers found 3348 that matched those keywords. The research journals were then filtered again by title and abstract, and 35 journals remained. Of the 35 journals that matched the title and abstract, full-text analysis was carried out, and texts that did not meet the inclusion criteria were excluded, leaving seven articles. Of the seven articles, analysis was carried out with critical appraisal based on the type of journal, and two articles were excluded because they did not meet the inclusion criteria. Therefore, five journals were synthesized. The literature collection process can be seen on the PRISMA (preferred reporting items for systematic review and meta-analysis) chart, which is shown in Figure 1.

### 3.2. Study Design and Aims

Of the five articles reviewed, the exergame tools used as interventions are quite diverse. One article uses the Kinect system box, one article uses interactive cycling, one article uses a combined cognitive-aerobic bicycle, and two articles with the same researcher use Senso Dividat. The range of interventions given by the five articles varied from 8 weeks to 12 weeks, and the frequency of exercise was three to five times per week. An explanation of the intervention, dose, and follow-up time can be seen in Table 1.

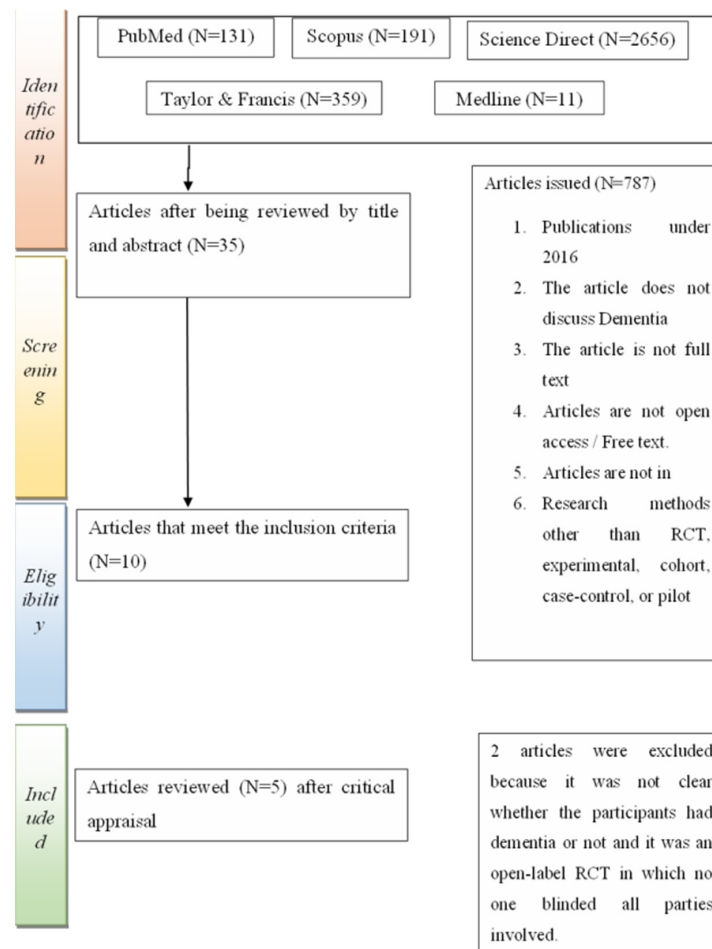


Figure 1. Journal review flow.

Table 1. Method, interventions, dosages, follow-up time, and results.

Study	Method (Desain Sample, Variable, Instrument, and Analys)	Group Treatment	Group Control	Follow-Up	Results
Jiaying Zheng et al. [10]	D: Randomized controlled trial S: Convenience sampling V: Exergame group, I: MMSE A: Pre-post comparative design	For 8 weeks with a frequency of exercise 5 days/week with a duration of exercise 1 h/day. The exergame tool used is a Kinect system box, which has a Kinect sensor and a console (for game control). Participants were asked to sit in a chair 1–1.5 m away from the Kinect sensor so that their position and movement could be detected by the infrared camera on the sensor. The game played is The Kinect Fruit Ninja game, where participants are asked to cut the fruit to obtain points. If the participant cuts the bomb, there will be a point deduction. In addition, participants received treatment as usual (not explained what kind of special treatment) and received treatment as usual within 8 weeks. Eighth week after the initial intervention.	Receive the usual care within 8 weeks.	Eighth week after the initial intervention.	There was no significant difference in MMSE scores ( $p = 0.252$ ). There was an increase in the MMSE score in the intervention group, although it was not significant.

**Table 1.** *Cont.*

Study	Method (Desain Sample, Variable, Instrument, and Analys)	Group Treatment	Group Control	Follow-Up	Results
Esther et al. [11]	<p>D: Controlled trial                      S: Convenience sampling                      V: Interactive cycling                      I: MMSE                      A: Intention to treat (ITT) analyses</p>	<p>Group Exergames: The intervention was given in 12 weeks with a frequency of 3x/week, with each session lasting 30–50 min. Participants were given an exergame exercise in the form of a combined cognitive–aerobic bicycle exercise developed by Bike Labyrinth. This exergame tool is a stationary bicycle connected to a video screen, and participants are asked to follow a bicycle route through a digital environment and jointly participate in cognitive tasks. The cognitive training task has seven levels of difficulty, so cognitive training becomes a permanent challenge for participants. Static Bike Group: Intervention was given in 12 weeks with a frequency of 3x/week. Participants were given cycling exercises on a stationary bicycle for 30 to 50 min. The intervention was given for 12 weeks with a frequency of 3x/week. Participants in this group were given exercises containing relaxation and flexibility exercises with an exercise time of 30 min in Week 12 (T2) and week 24 (F1) at the time of the initial intervention.</p>	<p>The intervention was given in 12 weeks with a frequency of 3x/week. Participants in this group were given an exercise containing relaxation and flexibility exercises with a 30 min exercise time.</p>	<p>Week 12 (T2) and week 24 (F1) after the initial intervention.</p>	<p>There was an increase in cognitive function in the exergame group on MMSE at T2 (<math>r = 2.30</math>, 95% CI: 0.65, 3.96, <math>p = 0.007</math>) and TMT-A at T2 (<math>r = -28.98</math>, 95% CI: <math>-54.89</math>, <math>-3.08</math>, <math>p = 0.029</math>).</p>
Joeke van Santen et al. [12]	<p>D: Randomized controlled trial                      S: Purposive sampling                      V: Combined cognitive aerobic bicycle                      I: TMT-B, the abbreviated 5-line Stroop color–word test interference score, letter fluency, the rule of shift cards, location learning test—revised, WAIS-III digit span, WMS-III spatial span                      A: Pre-test–post-test design</p>	<p>For 6 months with a frequency of 5 times/week. The interventions provided were a program of regular activities (music, arts and crafts, and physics exercises such as walking outside) and interactive cycling using a stationary bicycle linked to a screen. Carry out an activity program regularly within 6 months and exercise frequency 5x/week. Three (T1) and six (T2) months reward intervention.</p>	<p>Perform a regular activity program within 6 months and exercise frequency 5x/week.</p>	<p>Third (T1) and 6th (T2) months of initial intervention.</p>	<p>Participants who joined the exergame group had a better increase in cognitive function on MoCA (<math>n_2p = 0.385</math>, <math>p = &lt;0.001</math>).</p>

Table 1. Cont.

Study	Method (Desain Sample, Variable, Instrument, and Analys)	Group Treatment	Group Control	Follow-Up	Results
Nathalie Swinnen et al. [13]	D: Pilot randomized controlled trial S: Purposive sampling V: Dividat Senso I: MoCA A: Pre-test–post-test comparative design	The intervention lasted for 8 weeks, and the intervention was in the form of exergame and care as usual, with exergame carried out 3x/week. Participants walked first to the practice room for about 10 min before using the exergame tool for 15 min. Dividat Senso tool has a platform with sensitive steps (left, right, up, and down) with changing pressure and a connected interface. If the game gives an order for the patient to step to the right or the left, then the participant must step with the same side foot. For the sequence of steps, forward or backward, participants can use the desired foot. Intervention lasting 8 weeks, the intervention is in the form of listening to love and affection music, as usual, carried out 3x/week with a duration of 15 min. Participants walk first to the practice room for about 10 min, then watch and listen to the desired music on the TV in the same room as the exergame room. The eighth week after the initial intervention.	The intervention lasted 8 weeks, the intervention was in the form of listening to favorite music, and treatment, as usual, was carried out 3x/week with a duration of 15 min. Participants walked first to the exercise room for about 10 min, then watched and listened to the desired music on the TV in the same room as the exergame room.	Eighth week after the initial intervention.	Participants who joined the exergame group had a better increase in cognitive function on MoCA (n2p = 0.385, p = <0.001).
Nathalie Swinnen et al. [14]	D: Qualitative study S: Purposive sampling V: Dividat Senso I: Semi-structured interviews A: Thematic analysis	The intervention lasts 8 weeks with a frequency of 3x/week (24 sessions in total exercise). Every session practice is filled with walking going to room practice, and coming back from room exercise, as well as using a tool exergame, namely 'Dividat Senso'. To use this tool, a participant steps on footing shaped child arrow (to the direction right, left, up, and down). Participants first stand in the middle platform and then interact with the screen interface with the method step on footing child arrow by instruction from the screen. Practice every participant conducted in a room separated and each supervised one person to ensure comfort and safety.		Fourth (mid) and eighth (post) week after the initial intervention.	Some participants reported increasing positive effects on their attention and concentration. Thirty-three participants indicated that the exergame stimulated attention and concentration required.

The five articles reviewed showed varying effects on cognitive function in patients with dementia. Only three articles showed a significant improvement in the cognitive abilities of people with dementia after being given exergame exercises, while the other articles did not show significant changes. In a study conducted by Jiaying et al. [10], where 20 participants in the treatment group used the Kinect system box and received usual care, and 18 participants were in the control group and received usual care, there was no significant difference in MMSE scores in comparison of the two groups after the intervention ( $p = 0.252$ ) [10]. There was an increase in the MMSE score in the treatment group compared to before the intervention, although it was not significant. In order to achieve a significant difference, the  $p$ -value must be less than 0.06 ( $p = <0.06$ ) [10].

In contrast to Jiaying’s study, which was conducted by Joeke Van et al. [12], where 73 participants were in the treatment group using interactive cycling and regular activity, and 39 participants were in the control group with only regular activity, there was a positive change in cognitive function. The results after the intervention showed a statistically significant increase in the treatment group compared to the control group on MMSE at T2 ( $p = 0.07$ ) and TMT-A at T2 ( $p = 0.029$ ), where an effect can be said to be significant if the  $p$ -value is less than the same with 0.05 ( $p < 0.05$ ) [12].

Slightly different from the research conducted in the four other articles, in the research conducted by Esther et al. [11], 38 participants in the exergame group used a combined

cognitive–aerobic bicycle, 28 participants in the aerobic group used a stationary bicycle, and 39 participants in the active control group completed relaxation and flexibility exercises, and the functioning of four cognitive domains was evaluated (executive function, psychomotor speed, episodic memory, and working memory) [11]. At T2, of the four cognitive domains, only psychomotor speed was found to be increased in the exergame group compared to the active control group ( $p = 0.047$ ), while the other three cognitive domains did not show a significant difference. In the F1 analysis, it was found that the increase in psychomotor speed was still maintained in the exergame group compared to the active control group ( $p = 0.014$ ), but no significant difference was found when compared to the aerobic group ( $p = 0.399$ ) [11]. Apart from speed psychomotor, no differences were found between groups in the other three cognitive domains.

In contrast to other studies, the research of Nathalie Swinnen et al. [14], involving 31 participants with a diagnosis of MNCD is a qualitative study that focuses on knowing the views and experiences of participants after getting an exergame intervention. The exergame tool used was Dividat Senso, and there was no comparison group [14]. Data collection was performed through one-on-one interviews with participants. Some participants noticed an increase in their attention and concentration ( $n = 6$ ), and there was an additional statement that the games used for training stimulated their attention and concentration so that they needed focus ( $n = 13$ ) [14]. In addition, some participants gave spontaneous statements if their reaction to time also increased ( $n = 3$ ). A number of other participants also said the change was an increase in their memory ( $n = 7$ ) [14].

Nathalie Swinnen et al. [13] also conducted a study on 22 participants in the treatment group using sensory individuals and 23 participants in the control group with the intervention of listening to favorite music in patients with MNCD [13]. The treatment group had a significant improvement in cognitive function when measured by MoCA compared to the control group ( $p = <0.001$ ).

## 4. Discussion

### 4.1. The Effect of Physical Exercise on Cognitive Improvement

Exergame is a combination of exercise and gaming, so the training provided involves physical exercise and a game tool. Physical exercise helps the production of peripheral brain-derived neurotrophic factor (BDNF), increases blood flow, improves cerebrovascular health, and influences the process of glucose and lipid metabolism in bringing nutrients to the brain [15]. In MCI patients, peripheral BDNF levels have a significant decline [16]. BDNF itself is a member of the neurotrophin growth factor family that potentiates synaptic strength and plasticity underlying learning and memory [16].

Some evidence suggests that BDNF can be a link between plasticity and physical activity [17]. A study conducted by Skilleter et al. [16], on healthy adult participants shows that the inferior parietal lobe has an SII that functions to receive somatosensory stimuli from the thalamus and the contralateral side of the SII, then integrates with visual or audio input to perform several level command functions. Higher levels include sensorimotor planning, spatial recognition, stereognosis, and some involvement in learning and language [18].

Many studies have shown that physical exercise can determine structural changes, such as increasing gray matter volume in the frontal lobe and hippocampal area and reducing damage to gray matter areas. In addition, physical exercise also prevents cognitive decline associated with aging, declines in executive function, reduce the risk of dementia, and improves the quality of life [15]. It has been proven that cognitive function is most influenced by brain maturity (such as attention or cognitive flexibility), and the cognitive functions most dependent on experience (such as memory) are the cognitive functions most sensitive to physical exercise.

### 4.2. Exergame Effectiveness and Dosage

Of the five articles reviewed, only the research conducted by Joeke et al. [12] and Nathalie Swinnen et al. [13,14] showed a positive effect after the administration of exergame

on cognitive improvement in patients with MNCD or dementia. In the study of Joeke van et al. [13], the intervention was given within a period of 6 months, and the frequency of exercise was 5x/week. The length of time using this exergame can be a factor in increasing cognitive function in patients with dementia.

In the qualitative research and pilot RCT conducted by Nathalie Swinnen et al. [13,14], the duration of the intervention was 8 weeks with a frequency of exercise 3x/week. Although it is less than that given by Joeke van et al. [12], in the RCT pilot study Nathalie Swinnen et al. [13], the average attendance of exergame group participants in the exercise program reached 82.9% with 19 participants achieving a 70% attendance of the exercise session, which shows participants' obedience in performing the exercise [13]. This can be one of the causes of the increased cognitive function of the intervention group participants after 8 weeks of exercise.

In a study conducted by Jiaying et al. [10], there was no significant increase in cognitive function. The duration of the intervention was 8 weeks, the frequency of exercise was 5x/week, and the duration of the exergame was 1 h/day. Researchers suspect that this insignificant change in cognitive function is because the intervention time is not long enough or because the intensity is not high enough. In addition, there is a possibility that the cognitive measurement tool used (MMSE) is not sensitive enough to detect cognitive changes in a short training period [10]. Researchers also suspect that this cognitive increase is not significant because researchers only provide one game in 8 weeks, so the final measurement results are not effective.

Research conducted by Esther et al. [11] also did not show a significant increase in cognitive function. The duration of the intervention given was 12 weeks, the frequency was 3 weeks, and the duration of the exergame was around 30–50 min [11]. Of the four cognitive domains examined, only psychomotor speed increased. The increase in psychomotor speed in the exergame group was not maintained as significantly as the aerobic group at follow-up at week 24. Researchers suspect several reasons why the exergame exercise given to the exergame group did not show a greater effect on cognitive function than the aerobic group. First, participants need more time to master the given exergame, where the researcher only provides training for 3 months so that it might trigger a synergistic effect from the late exergame [11]. Second, because the participants are people diagnosed with MNCD, who have less structural brain capacity, it is difficult for them to receive the cognitive enhancement benefits from exergame compared to MCI or healthy elderly [11].

The duration of the intervention is one of the factors for the success of the intervention. As previously mentioned, physical exercise is one of the most effective ways to increase circulating levels of BDNF. The type of exercise mentioned has the effect of increasing BDNF, namely aerobic exercise. A study demonstrated the effect of 3 months of aerobic exercise on increasing hippocampal volume by 12% in healthy individuals and 16% in individuals with schizophrenia [17]. It was reported that 3 months of endurance training in young adults could increase the release of resting BDNF from the brain [19].

For the duration of exercise alone, there was a significant increase in serum BDNF concentrations both in healthy individuals and in multiple sclerosis patients after being given 30 min of cycling exercise with a VO<sub>2</sub> max of 60 percent [19]. However, there was no significant improvement after 10 min of moderate-intensity aerobic cycling exercise. Another study also showed an increase in serum BDNF concentrations after being given step exercise for 15 min with high intensity [19].

Of the five articles reviewed, the duration of the exergame intervention on how far cognitive function improved was still inconsistent. This may be related to other factors, such as the outcome measurement tool, which is less sensitive. The study of Nathalie Swinnen et al. [13], which used MoCA with a shorter training time, had a more visible cognitive enhancement effect than the study of Jiaying et al. [10], which used MMSE. However, it should be noted that the outcome measure used by Nathalie Swinnen et al. [13] must also be considered because it uses MoCA, which is designed to examine MCI so that it may be easier to see improvements compared to MMSE.

From the above results, exercise using an exergame will be effective in improving cognitive function in cases of dementia if the exercise duration is adjusted appropriately. Exercise can be given for 3 months or 12 weeks with a duration of 15–30 min or more according to the given intensity so that the level of BDNF release in the brain is significant. In addition, the level of difficulty given must also follow the patient's ability, and participant obedience in participating in the training session is also another factor in increasing the effectiveness of the exercise.

## 5. Conclusions

From the five articles that were reviewed, it can be concluded that giving exergame exercise can be recommended to improve cognitive function in cases of dementia. Exergame is one of the most effective and fun interventions to be applied to patients so that it not only has a positive effect but also makes patients, who are mostly elderly people, more motivated and disciplined in carrying out exercises.

Things that must be considered in providing exergame exercises are adjusting the level of difficulty with the initial ability of the patient and the duration of the intervention. The dose of exergame exercise that can be given is about 12 weeks, with the duration of exergame usage ranging from 15 to 30 min or more, depending on the intensity given. Patient compliance is also an important factor in the success of the intervention given.

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