ISSN 2354-8428
e-ISSN 2598-8727

JURNAL KEPERAWATAN

# KOMPREHENSIF

*COMPREHENSIVE NURSING JOURNAL*

***Published by :***

**Sekolah Tinggi Ilmu Keperawatan PPNI Jawa Barat**

Vol. 10 No. 5, October 2024



| JURNAL KEPERAWATAN KOMPREHENSIF | VOL. 10 | NO. 5 | Bandung October 2024 | ISSN 2354-8428 | e-ISSN 2598-8727 |
|---|---|---|---|---|---|

p-ISSN : 2354 8428 | e-ISSN: 2598 8727

Jurnal Keperawatan Komprehensif
Volume 10 Issue 5 October 2024

Research Article

# The Effect of Application-Based Exergames on Cognitive Function in Hemodialysis Patients

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Received : 29/09/2024
Revised : 26/10/2024
Accepted : 27/10/2024
Online : 31/10/2024
Published : 31/10/2024

**Abstract**

**Aims**: Hemodialysis (HD) patients may disrupt physical and cognitive capabilities, affecting older mobility, independence, psychological well-being, and health care expenditures. Home-based exergame training overcomes accessibility issues.
**Methods**: This research examined how mobile app exergames affected cognitive performance in hemodialysis patients. This research used a repeated measurement-quasi-experiment two-group pretest-posttest design in a West Java. The intervention group trained three times a week for 30-40 minutes for two months, totaling 24 sessions (8 weeks). In the control group, participants were told to live normally.
**Results**: Inclusion criteria was performing HD at least twice a week, age > 65, living independently, self-reported health, ability to stand for 10 minutes without help, and access to a TV with HDMI connection. The Trail Making Test (TMT) measured psychomotor speed and executive function. ANCOVA was used to compare scores before and after the intervention in both groups. The repeated ANOVA test revealed that the trial making test A (TMT A) decreased significantly in the intervention group after one month intervention (T2) (from 79.77 ± 7.23 at baseline to 40.87 ± 5.33 at follow up), with the effect size was 0.41, indicating moderate effect size. The trial making test B (TMT B) decreased significantly in the intervention group after one month intervention (T2) (from 77.6 ± 24.2 at baseline to 70.32 ± 23.3 at follow up), with the effect size was 0.45, indicating moderate effect size. However, there was not significant change of Trial making Test A and B from baseline to follow up time in the control group.
**Conclusions:** Findings of this study could be one of the new solutions to help patients undergoing hemodialysis improve their cognitive function. Exergame training may be done at home, which helps to overcome accessibility constraints.

**Keywords:**
**Cognitive Function, Exergames, Hemodialysis, Mobile Application**

## INTRODUCTION

End-stage renal disease (ESRD) is a high-prevalence end-stage kidney disease that affects over 500,000 individuals in Asia. Hemodialysis (HD) is the treatment of choice for 64% of ESRD patients (1). Starting HD therapy at the age of 45,

https://doi.org/10.33755/jkk

p-ISSN : 2354 8428 | e-ISSN: 2598 8727

Jurnal Keperawatan Komprehensif
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patients have an average life expectancy of no more than 10 years and a significant mortality rate of 15% (2). Approximately 2-3 times per week, hemodialysis (HD) is administered, with each session lasting between 3-5 hours. This activity persists throughout one's lifetime. Nevertheless, this HD therapy is unable to cure the kidney disease that patients are experiencing; it is merely a means of ensuring their survival. Furthermore, HD patients frequently report experiencing numerous complications or adverse effects as a result of their HD therapy. One of them is the detrimental effect on cognitive and physical function, which can have an impact on daily activities such as decreased independence and impaired mobility (3). Furthermore, HD patients experience modifications in brain structure, including a substantial decrease in gray matter (GM) volume in the frontal, temporal, and subcortical regions, which may contribute to moderate cognitive impairment or dementia (4,5). The decline in physical and cognitive function is influenced by changes in lifestyle and circumstances, in addition to age-related factors (86).

According to a meta-analysis, mild to moderate cognitive decline is experienced by 45-70% of HD patients, while 20-25% develop dementia (7). The mildest form of cognitive impairment, amnesia, is estimated to be experienced by 39% of HD patients aged 50-59 years, with this number increasing to 85% at the age of over 80 years (8). Cognitive decline can manifest in this manner. This phase is characterized by the onset of difficulty in recalling previously acquired information, a condition that is not uncommon in middle-aged individuals. Despite this, an individual can continue to function normally. The most severe clinical form is dementia, which can develop from moderate cognitive impairment because of this amnesia (9). Furthermore, the survey indicated that HD patients are highly dependent on others to perform their daily activities. The quality of life in HD patients is significantly impacted by the decline in physical functional status (10). According to a hypothesis, the human brain and body are plastic and adapt in response to experience and stimulus (11). Consequently, cognitive function can be preserved with an intensive stimulus, despite the degenerative decline observed in HD patients (12). Nevertheless, there is still a scarcity of interventions that can be implemented to enhance stimuli that can influence neuronal plasticity. An intervention is required to promote healthy aging by identifying effective strategies that stimulate experience-based (neuro) plasticity.

A behavioral strategy to improve HD patients' physical and cognitive performance. Previous research has demonstrated that physical activity has a variety of beneficial impacts on the human body (13). The cardiovascular and respiratory systems, metabolism, immune system, and body composition are all enhanced by physical exercise (14). Furthermore, longitudinal and cross-sectional research and interventions have demonstrated the beneficial effects of physical activity and exercise on the cognitive processes and psychological well-being of older individuals (15,16). Positive effects on various brain structures, particularly increased brain volume in the frontal cortex and hippocampus, have been observed in animal and human studies at the brain level, which are the areas most affected during the aging process (15-17).

Neuroplasticity associated with training is believed to be significantly influenced by changes in neurotransmitters and/or neurotrophic factors (18). For instance, exercise may enhance neuroplasticity by increasing the expression of neurotrophins, including vascular endothelial growth factor (VEGF), brain-derived neurotrophic factor (BDNF), and insulin-like growth factor 1 (IGF-1) (17, 19, 20). In addition to physical exercise, cognitive training and challenging environments also contribute to the enhancement of cognitive performance and the modification of specific brain structures

https://doi.org/10.33755/jkk

p-ISSN : 2354 8428 | e-ISSN: 2598 8727

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toward the better. Results of meta-analyses and evaluations indicate that cognitive training may be advantageous for elderly individuals (21,22). Cognitive training appears to be highly effective in enhancing a variety of cognitive functions, such as memory, executive function, attention, visuo-spatial abilities, and processing speed (27). Furthermore, cognitive stimulation has been demonstrated to enhance the production of BDNF (24). Exergames are a promising method of interactive physical-cognitive training. Exergames are digital games that necessitate physical activity to be played (25). Cognitive stimulation may be embedded in virtual reality/gaming scenarios to varying degrees of explicitness and specificity. Exergames are recognized for their ability to enhance training motivation by "gamifying" the training process, resulting in engaging and pleasurable games (26). This research examined how application-based exergames affected physical and cognitive performance in hemodialysis patients.

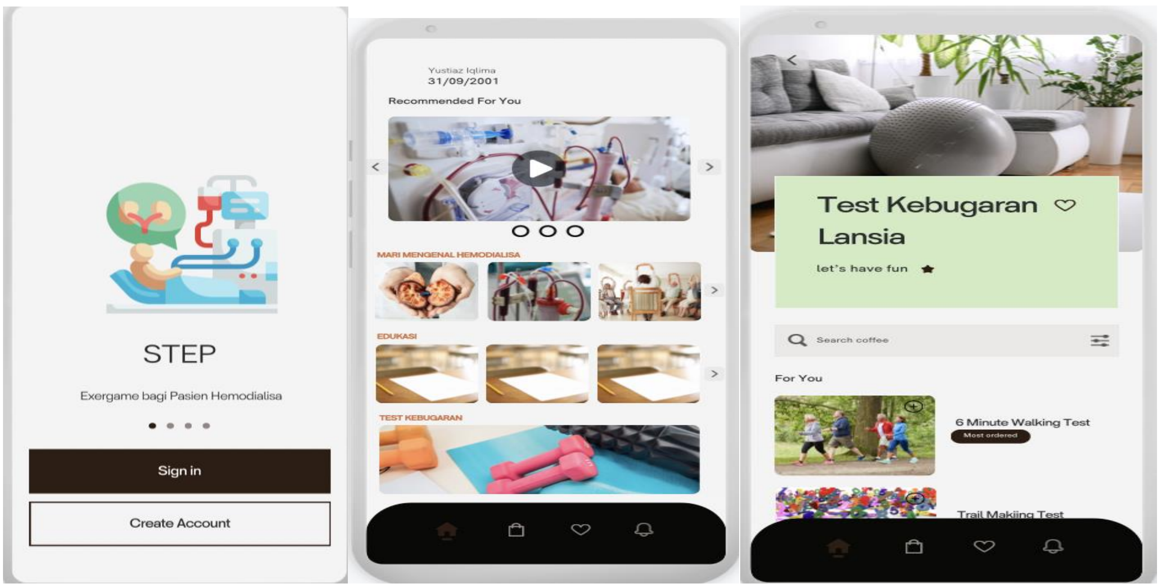
## METHODS

### Study design

A repeated measurement-quasi-experiment two-group PreTest-PostTest design was employed in this study at an HD clinic in West Java. A control group and an intervention group were included in this investigation. The intervention be administered for a period of two months, following which data collection conducted twice: immediately following the intervention and one month after the intervention.

### Intervention

The content of the exergame application was developed through literature evaluations and Focus Group Discussions (FGD) with experts, in collaboration with researchers and information and technology (IT) specialists. The exergame is a game that includes exercises to make exercise more pleasant for HD patients, in accordance with the sports recommendations for HD patients. The application's navigation design comprises the following: Registration menu, Log in/Log out, Exercise game, Health education, Exercise diary and reward, and Online consultation (Figure 1).



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### Sample

The convenience sampling technique was employed to conduct the sampling. The estimation of sample measurements was conducted using G-Power software version 3.1 with the F-test, ANCOVA: Fixed effect, main effects, and interactions assuming two tails, α = 0.05, Effect size = 0.35, power level = 0.95, and a minimum sample estimate of 109. The total sample size is 120 respondent.

Inclusion criteria included HD patients who were over the age of 20, had been undergoing HD for a minimum of six months, were cooperative and compos mentis aware, and were willing to participate as respondents. People who were unable to perform functional tests or planned interventions, those with lower extremity vascular access (VA), those who had suffered myocardial infarction in the previous 6 weeks, those with unstable angina during exercise or at rest, those with lower limb amputation above the knee (without prosthesis), those with cerebral vascular disease such as stroke or transient ischemia, those with skeletal muscle changes, those with respiratory disease that worsens with exercise, and those who could not perform functional tests or planned interventions were excluded.

### Instrument

The Trail Making Test (TMT) evaluates psychomotor and functional skills (45). In the initial section (TMT A), the participant is obligated to connect the numbers from 1 to 25 in the most expedient manner possible, ensuring that they are connected accurately and sequentially. In the second section of the test (TMT B), the stimuli were letters and numerals that were circled. The numbers and letters that are accurately identified must be connected in a numerical and alphabetical order that is as precise as possible (e.g., 1 – A – 2 – B – 3 – C – ...). TMT A evaluates the speed of psychomotor processing and the intensity of visual exploration, while TMT B also evaluates cognitive flexibility. The number of seconds required to complete the task is the metric used to report the results of both TMT A and B. Consequently, scores that are higher indicate a larger degree of impairment.

### Procedure

Pre-test assessment was conducted 1 week before the intervention and was conducted. Before and after measurements were conducted approximately on the same day for each participant. The intervention period lasted for 12 weeks.

Participants in the intervention group used the exergame application where participants train three times per week for 30-40 minutes for 3 months resulting in a total of 24 training sessions. The frequency and duration of training follow previous exergame studies that describe positive effects in the elderly and current recommendations for physical activity and fall prevention in the elderly (42). Training was conducted at the participants' homes with the guidelines of the developed mobile application. For installation and instruction, researchers visited the participants at home. Training sessions were scheduled individually by the participants considering the guidelines of three training sessions per week and no more than one training session per day. In addition, participants received written recommendations on how to adjust the training challenges progressively while the training intensity was targeted (43). All training sessions were recorded by the participants in a training diary.

The control group participants were directed to maintain their usual daily routines. All participants, including those in the intervention and control groups, were contacted biweekly to assess deviations in their typical physical and cognitive activity patterns, alongside study-related activities. Furthermore, participants in the training group were inquired about possible safety concerns during the training and received assistance if technical or content-related problems occurred.

https://doi.org/10.33755/jkk

p-ISSN : 2354 8428 | e-ISSN: 2598 8727

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**Data analysis**

Statistical analysis of the behavioral data was performed utilizing SPSS 23.0 for Windows (SPSS Inc., Chicago, Illinois, USA). A p-value below 0.05 ($p < 0.05$) was deemed statistically significant. Training diaries were employed to assess participants' adherence to the intervention, with a stipulated compliance threshold of 70% necessary for inclusion in the analysis. Descriptive statistics, comprising frequency, median, and interquartile range, were computed for all data. The ANCOVA test was utilized to evaluate the differences in pre- and post-intervention scores between the two groups.

## RESULTS

In the intervention group, the mean age was 55.50 ± 10.72, 55.7% male, 51.6% had education level above senior high school, 90.7% married, and 69.1% unemployed. The average length of HD was 9.87± 3.29, number of comorbidities was 1.41±0.32, IDWG was 5.10±2.26, Hb was 9.85±1.32 g/dL, ureum was 69.35±16.94 mg/dL, and creatine. While, in the control group their mean age was 53.65±10.94, 61.9% male, 56.7% had education level above senior high school, 84.5% married, and 61.9% unemployed. The average length of HD was 8.10± 4.03, number of comorbidities was 1.77±0.56, IDWG was 4.21±2.28, Hb was 8.98±1.27 g/dL, ureum was 71.10±18.07 mg/dL, and creatine was 8.11±3.25 mg/dL. There were no significant differences between the intervention and comparison conditions on age, gender, education level, marital status, employment status, number of comorbidities, Hb, ureum, and creatinine level ($p>0.05$).

The majority of the participants had deficient of trial making A test, and there was no significant difference between the intervention and control groups at the beginning of the study. The repeated ANOVA test revealed that the trial making test A (TMT A) decreased significantly in the intervention group after one month intervention (T2) (from 79.77 ± 7.23 at baseline to 40.87 ± 5.33 at follow up), with the effect size was 0.41, indicating moderate effect size. However, there was not significant change of Trial making test A from baseline to follow up time in the control group (p-value= 0.578) (Table 1).

**Table 1. Comparison of Trial Making A test scores in control and intervention group at different time points by ANOVA test**

| Variable | T0 | T1 | T2 | F | ANOVA Test | Cohen's d | Interpretation |
|---|---|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | Mean ± SD | | p-value | | |
| Intervention group | 79.77 ± 7.23 | 65.01 ± 7.20 | 40.87 ± 5.33 | 11.897 | 0.001 | 0.41 | Moderate effect size |
| Control group | 78.15 ± 7.46 | 79.06 ± 8.21 | 78.34 ± 6.52 | 0.578 | 0.453 | 0.03 | No effect size |

Note: P < 0.05 are considered significant; baseline (T0), imediately after intervention (T1), and at one month aftre intrevention (T2)

The majority of the participants had deficient of trial making B test, and there was no significant difference between the intervention and control groups at the beginning of the study. The repeated ANOVA test revealed that the trial making test B (TMT B) decreased significantly in the intervention group after one month intervention (T2) (from 77.6 ± 24.2 at baseline to 70.32 ± 23.3 at follow up), with the effect size was 0.45, indicating moderate

https://doi.org/10.33755/jkk

p-ISSN : 2354 8428 | e-ISSN: 2598 8727

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effect size. However, there was not significant change of Trial making test B from baseline to follow up time in the control group (p-value= 0.872) (Table 2).

**Table 2. Comparison of Trial Making Test B in control and intervention group at different time points by ANOVA test**

| Variable | T0 | T1 | T2 | F | ANOVA Test | Cohen's d | Interpretation |
|---|---|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | Mean ± SD | | p-value | | |
| Intervention group | 277.6 ± 24.2 | 132.1 ± 16.2 | 70.32 ± 23.3 | 23.322 | 0.001 | 0.45 | Moderate effect size |
| Control group | 268.3 ±23.5 | 270.0 ± 28.3 | 267.2 ± 26.5 | 0.121 | 0.872 | 0.03 | No effect size |

Note: P < 0.05 are considered significant; baseline (T0), imediately after intervention (T1), and at one month aftre intrevention (T2)

## DISCUSSION

This study found that exergame-based mobile application has potential significant impact on psychomotor and functional skills as measured by Trial Making Test A and B among patients undergoing hemodialysis. In general, it has been shown that exergame training may increase cognitive functions, particularly executive skills (28,29), as well as physical functions (cardiovascular or musculoskeletal system), depending on the physical components and exercises that are included into the training (for example, stepping or cycling) (30). Exergaming seems to be more helpful for cognitive progress in older persons than conventional cognitive or physical training (for example, aerobic exercise) (28,29). Exergaming appears to be equally or somewhat more effective than traditional practices. At the level of the brain, two studies (31, 32) examined the changes that occurred in the structure of the brain as a result of exergame training. This training technique has been shown to increase cognitive processes, particularly executive skills, according to a number of earlier research (33, 34). These investigations involved combined physical-cognitive training as well as exergaming. Recent reviews and meta-analyses have indicated considerable gains in executive functions after the implementation of exergame training (35).

As a consequence, our findings are consistent with the data that has been presented by these studies. Possibly connected to the cognitive stimulation that is more or less openly included in the game settings of exergames is the possibility that this is happening. However, it has also been shown that workouts that focus on coordination, such as dancing, as well as aerobic and weight training, may increase cognitive performance (36,37). Previous studies have revealed that older individuals who participated in exergame training saw improvements in a variety of physical functions (for example, in the cardiovascular or musculoskeletal system). These gains were found to be contingent upon the physical and exercise components that were included into the training (for example, stepping or cycling) (38). An exergame research that used an intervention that was comparable to the one that we used shown that gait characteristics such as walking speed improved following exergame training, particularly when the participants were walking while doing two tasks at the same time (39). A discussion is held on the use of exergaming as a means of training dual-tasking skills, which are essential for

p-ISSN : 2354 8428 | e-ISSN: 2598 8727
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activities of daily living as well as for the avoidance of falls and safe gait in older individuals (40). Consequently, the invention of an exergame, which is a mix of exercise and game, is the innovative aspect of this research. The exergame is intended to stimulate neuroplasticity, which is a phenomenon that happens in HD patients.

This study has some limitation. First lack of randomization that could affect to the selection bias. Sample size was small, which may limit the generalizability of this study. However, this study probably the first conducted in hemodialysis patients in West Java that applied repeated measure that could be assessed potential long-term impact of the intervention.

## CONCLUSION

This study found that exergame-based mobile application has potential significant impact on psychomotor and functional skills as measured by Trial Making Test A and B among patients undergoing hemodialysis. Findings of this study could be one of the new solutions to help patients undergoing hemodialysis improve their cognitive function. Exergame training may be done at home, which helps to overcome accessibility constraints.

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