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The effect of a virtual reality exergame on handgrip strength and cognitive function in post-stroke patients

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ABSTRACT

Background: More than 60% of stroke patients have chronic neurological impairments that impair hand strength and cognitive function, lowering their quality of life. While virtual reality (VR) exergames have been extensively researched as adjuvant therapies, evidence of their simultaneous effects on motor and cognitive skills is scarce. This study aimed to evaluate the impact of VR exergames on handgrip strength and cognitive function in post-stroke patients.

Methods: The study used a randomized controlled trial design with 60 subacute post-stroke patients who were randomly assigned to either the control group, which received conventional care (occupational therapy and physiotherapy), or the intervention group (conventional care plus VR exergame therapy) for eight weeks. This study included first-time stroke patients with onset ≥1 month, mild to moderate hemiparesis (MMT ≥ 3), and hemodynamic stability. Participants with significant spasticity (MAS > 3), aphasia, or uncontrolled comorbidities were excluded. Before, during, and after the intervention, handgrip strength and cognitive function were tested using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina).

Results: After 8 weeks of therapy, the intervention group showed a significant increase in handgrip strength (+3.9 points, *p*-value= 0.040) and MoCA-Ina scores (+5 points, *p*-value= 0.007) compared to the control group.

Conclusion: Integrating VR exergames with conventional rehabilitation significantly improves handgrip strength and cognitive function in post-stroke patients compared to traditional therapy alone.

Keywords: cognitive function, hand grip strength, stroke, virtual reality exergame.

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INTRODUCTION

Stroke is the primary cause of long-term impairment in adults, impacting around 15 million people globally each year, according to the World Health Organization.[1] Globally, one in every six stroke patients dies, and more than 60% of survivors have chronic neurological abnormalities that greatly affect their quality of life, particularly in daily tasks.[2] Additionally, 40-80% of stroke patients may not fully restore upper limb function within 3 to 6 months of the stroke. Cognitive abnormalities are also prevalent, affecting around 74% of cortical stroke patients, 46% of subcortical stroke patients, and 43% of infratentorial stroke patients.[3]

Cognitive impairment can exacerbate disability and impede functional recovery in post-stroke patients due to low involvement and compliance with rehabilitation programs.[4] The variety of cognitive deficiencies, as well as the absence of evidence-based, standardized guidelines across all cognitive domains, continue to be significant barriers to effective cognitive rehabilitation.[5]

Conventional stroke therapy is an evidence-based technique that helps stroke patients improve their strength, flexibility, endurance, functional mobility, balance, gait, and quality of life.[6] However, its repetitious and monotonous nature frequently undermines patient motivation and adherence.[6,7] With technical breakthroughs, virtual reality (VR) exergames have emerged as a viable alternative, with considerable benefits in cognitive function, motor skills, muscle strength, and lower extremity balance.[7]

In recent years, video games have become increasingly popular for therapeutic reasons, particularly in connecting virtual stimuli to real-life circumstances.[7,8] However, there were few evidence-based studies and guidelines on rehabilitation that target handgrip strength measured with a dynamometer and cognitive function evaluated with the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina) test. Furthermore, the concurrent effects of VR exergames on hand motor and cognitive processes have not been investigated. The purpose of this study was to assess the association between virtual reality use and body function in post-stroke patients, with an emphasis on handgrip strength, cognitive performance, and the best exercise dose for long-term potentiation.

Table 1. Characteristics of research subjects

Characteristics	Intervention (n= 30) Mean±SD or n (%)	Control (n= 30) Mean±SD or n (%)	*P*-value
Age, years	58.43 ± 8.89	53.97 ± 11.09	0.091
Gender			
Male	21 (70.0)	16 (53.3)	0.184
Female	9 (30.0)	14 (46.7)	
Occupation			
Working	16 (53.4)	14 (46.7)	0.171
Not working	7 (23.3)	13 (43.3)	
Retired	7 (23.3)	3 (10.0)	
Stroke frequency			
1 time	28 (93.3)	27 (90.0)	0.640
2 times	2 (6.7)	3 (10.0)	
Hemiparesis			
Right	19 (63.3)	25 (83.3)	0.080
Left	11 (36.7)	5 (16.7)	
Disease onset, month	16.6 ± 29.1	9.9 ± 12.6	0.913
Comorbid			
Hypertension	22 (73.3)	21 (70.0)	
Hypertension+DM	0 (0.0)	3 (10.0)	0.194
Hypertension+cholesterol	8 (26.7)	5 (16.7)	
Hypertension+cholesterol+DM	0 (0.0)	1 (3.3)	
Medication			
Amlodipine+citicoline	24 (80.0)	20 (66.7)	
Amlodipine+citicoline+sugar medicine	0 (0.0)	4 (13.3)	0.113
Amlodipine+citicoline+simvastatin	6 (20.0)	6 (20.0)	

DM, diabetes mellitus; n, frequency; SD, standard deviation

METHODS

This study used a randomized controlled trial methodology to investigate the effects of VR exergame therapy on handgrip strength and cognitive function in subacute post-stroke patients. It was conducted at Dr. Tadjuddin Chalid General Hospital, Makassar, from November 2023 to March 2024, with 60 subacute stroke patients who were randomly assigned to two groups: (1) an intervention group that received conventional therapy (occupational therapy and physiotherapy, 30 minutes per session) plus VR exergame therapy using Music Glove Hand Therapy (30 minutes per session, three times per week), and (2) a control group that received only conventional therapy. Both groups received an eight-week intervention.

The study included first-time stroke patients with onset ≥1 month, mild to moderate hemiparesis (manual muscle testing (MMT) ≥ 3), and hemodynamic stability. Exclusion criteria were significant spasticity (Modified Ashworth Scale (MAS) > 3), aphasia, and uncontrolled comorbidities. Sampling was carried out utilizing consecutive sampling with sequence randomization.

A handgrip dynamometer (Camry Dynamometer Handgrip Digital EH101, China) was used to test grip strength, and the validated Indonesian version of the MoCA-Ina was used to assess cognitive function at baseline, week 4, week 8, and one week after therapy. Statistical analysis used the independent *T*-test or Mann-Whitney test for continuous variable and Chi-square for the categorical variable between-group comparisons. The paired *T*-test was used to analyze the within-group changes, and the Pearson or Spearman correlation test to investigate variable correlations. The Ethics Committee of the Faculty of Medicine at Universitas Hasanuddin, Indonesia authorized the study protocol (No. 97/UN4.6.4.5.31/PP36/2025), which ensured data confidentiality and participants' right to withdraw.

RESULTS

This study included 60 stroke patients from Dr. Tadjuddin Chalid Hospital in Makassar, who were equally divided into two groups: 30 in the control group and 30 in the intervention group. Baseline demographic and clinical factors such as age, gender, stroke history, disease onset, comorbidities, and medications did not differ significantly between the groups (Table 1).

No significant differences were found between groups from pre-therapy to week 4 (p-value = 0.276), post-therapy to one week post-therapy, or from week 4 to one week post-therapy (p-value = 0.060). The intervention group showed a significant improvement in handgrip strength (p-value = 0.040) from pre-therapy to week 8, from pre-therapy to one week post-therapy (p-value = 0.038), and from week 4 to week 8 compared to the control group (p-value = 0.021). These findings indicated that the addition of VR exergames enhanced handgrip strength after 8 weeks of intervention, with benefits

Table 2. **Comparison of changes in handgrip strength between the two study groups by Mann-Whitney test**

Measurement time	Intervention (n = 30)	Control (n = 30)	*P*-value
	Median (Min-Max)	Median (Min-Max)	
T0-T1	0.8 (0-4.0)	1.1 (0-4.2)	0.276
T0-T2	2.1 (0-7.6)	3.6 (0-7.0)	0.040
T0-T3	3.9 (0-7.2)	2.0 (0-7.4)	0.038
T1-T2	2.0 (0-4.2)	1.2 (0-4.2)	0.021
T1-T3	1.9 (0-5.0)	1.0 (0-4.0)	0.06[0]
T2-T3	0.0 (-0.5- 2.0)	0.0 (-1- 0.5)	0.932

Max, maximum; min, minimum; n, frequency; T0, pre-therapy; T1, during 4 weeks of therapy; T2, post-therapy or 8 weeks of therapy; T3, one week post-therapy.

Table 3. **Comparison of changes in cognitive function between the two research groups by Mann-Whitney test**

Measurement time	Intervention (n = 30)	Control (n = 30)	*P*-value
	Median (Min-Max)	Median (Min-Max)	
T0-T1	2.0 (0.0-6.0)	2.0 (0.0-4.0)	0.406
T0-T2	5.0 (1.0-8.0)	3.5 (1.0-9.0	0.007
T0-T3	5.0 (1.0-9.0)	4.0 (-15.0- 9)	0.003
T1-T2	2.5 (0.0-7.0)	1.0 (0.0-7.0)	0.022
T1-T3	3.0 (0.0-7.0)	1.5 (-18.0- 7)	0.007
T2-T3	0.0 (0.0-2.0)	0.0 (-19.0- 2)	0.329

Max, maximum; min, minimum; n, frequency; T0, pre-therapy; T1, during 4 weeks of therapy; T2, post-therapy or 8 weeks of therapy; T3, one week post-therapy.

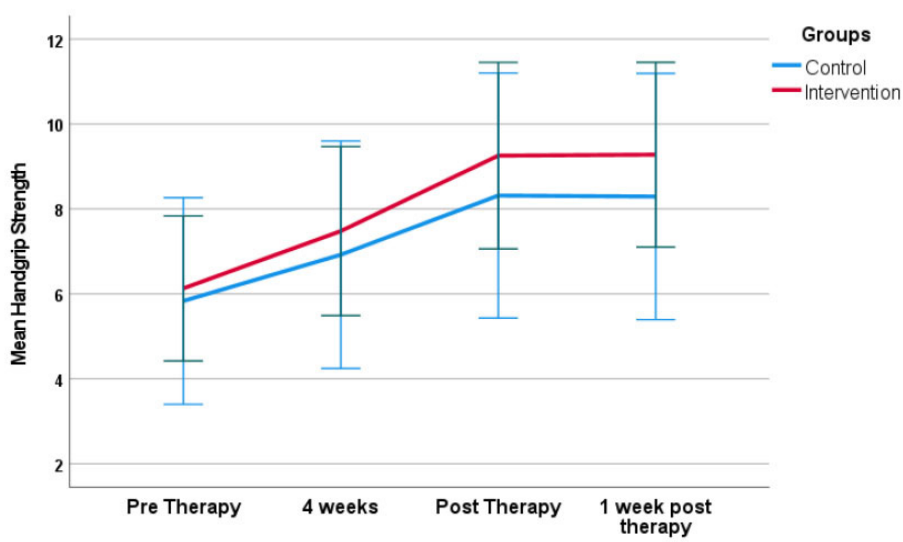

Figure 1. Comparison of handgrip strength based on measurement time in both groups.

lasting up to one week after therapy (Table 2, Figure 1).

Similarly, there were no significant differences in cognitive function between groups up to week 4 or from pre-therapy (*p*-value = 0.406). However, at week 8 and one week post-treatment, the intervention group demonstrated significantly greater improvements than the control group (*p*-values = 0.022-0.003). This suggested that VR exergaming provided additional cognitive benefits, particularly after long-term participation, with effects that persisted over time (Table 3, Figure 2).

DISCUSSION

In this study, combining traditional rehabilitation therapy with VR exergames dramatically enhanced handgrip strength after 4 and 8 weeks of treatment. These findings are comparable with those of Velmurugan et al., who found that stroke patients with poor gripping ability improved significantly in handgrip strength following four weeks of VR therapy, five sessions per week.[9] Adding a 1-hour VR-based therapy using Armeo Spring to a 1-hour conventional functional training program three times a week for three months resulted in significant increases in handgrip strength.[10] VR therapy encourages relaxation, a sense of accomplishment, and motivation, which improves patient involvement and contributes to greater upper extremity muscle strength.[9]

VR exergame treatment delivered twice weekly for three months increased handgrip strength in older individuals, although the improvement was not statistically significant.[11] However, the study did not indicate how many sessions would be held each week. In contrast, 30-minute exergame sessions, three times a week for eight weeks, dramatically enhanced handgrip strength in the same group. These data indicate that both the frequency and duration of therapy sessions may have an impact on treatment outcomes. Previous research supports this, demonstrating that VR exergame treatment applied 3-5 times per week for 4 weeks or 3 months effectively improved handgrip strength, especially in stroke patients.[12]

This study supports previous research that combines VR exergames with conventional therapy effectively enhances cognitive function in stroke patients. Cognitive improvements were observed after both 4 and 8 weeks of therapy. VR therapy, administered three times per week for four weeks, significantly improved MoCA-Ina scores in post-stroke patients.[13] Similarly, Rogers et al. found significant gains in MoCA-Ina scores following four weeks of VR therapy paired with conventional therapy, provided in three weekly sessions of 30-40 minutes for acute stroke patients.[14]

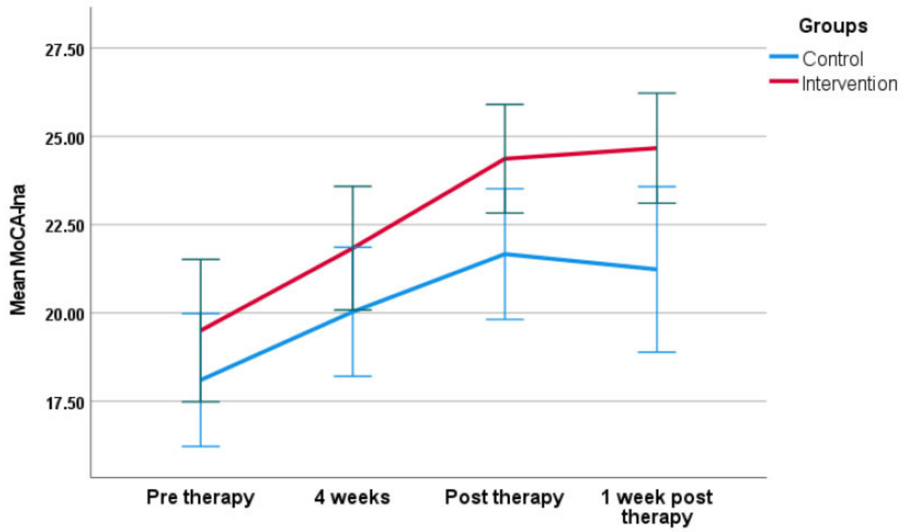

Figure 2. Comparison of cognitive function based on measurement time in both groups.

These findings could be explained by the use of exergame therapy in conjunction with traditional therapy, which includes goal-directed and exploratory upper limb tasks to improve motor and cognitive rehabilitation following stroke.[14] The combination encourages relearning through sensory-motor experiences, improves muscle control, neuromuscular coordination, and increases joint range of motion in the affected limbs. Furthermore, VR creates an interesting environment where patients may complete motor activities and handle virtual objects, enhancing motivation to continue therapy.[10]

This study found that when VR exergames are paired with traditional therapy, handgrip strength improves significantly after eight weeks of treatment. Exergames improve handgrip strength more than conventional therapies. The improvement can be attributed to both direct weight-bearing workouts that build muscles and indirect reduction in depression. Exergames have been demonstrated to increase muscle strength more than no exercise or regular treatment, and they provide additional advantages when combined with traditional therapy. Furthermore, exergames promote motivation, adherence, and movement proficiency, which contributes to increased handgrip strength.[15]

VR exergames have an indirect effect on handgrip strength by lowering depression. Daily sessions, six times per week for six weeks, resulted in considerably enhanced handgrip strength and decreased depression.[16] Eight weeks of VR exergame therapy alleviated depression in post-stroke patients.[17] VR exergames provide instant task feedback, as well as visual and audio stimulation, which increases interest, motivation, and stability in daily activities. This allows stroke patients to explore tasks independently, increasing autonomy. Handgrip strength has a substantial correlation with overall muscle strength, which is directly related to depression. Muscle weakness and depression are linked to deficiencies in hormone synthesis and neurological signal transduction pathways, such as androgen biosynthesis, steroid hormone control, and potassium channel function. Furthermore, interactions between the Ras homologous guanosine triphosphate-binding protein (RHO-GTPase) pathway, fibroblast growth factors, and cytokine receptors may have an impact on grip strength and depression via actin control, neurodevelopment, skeletal muscle development, and inflammatory responses.[18]

A three week VR intervention resulted in faster functional recovery than conventional therapy alone in sub-acute stroke patients with cognitive impairment.[19] VR exergames have also been found to improve cognitive performance, with balance and sports games influencing prefrontal brain activity while walking and boosting executive function.[11] These advantages could be mediated by neuroplastic mechanisms such as neurogenesis, synaptogenesis, and angiogenesis, as physical activity and cognitive stimulation, alone or in combination, cause structural and functional brain changes.[20] Repetitive physical activities improve cognitive performance by engaging brain areas responsible for cognitive processing.[13]

Exergames are classified as dual tasks because they require simultaneous cognitive and motor engagement via a human-video game interface.[15] VR exergames have a dual-task effect on cognitive function, which is linked to pathways involving brain-derived neurotrophic factor. Cognitive benefits are associated with higher plasma brain-derived neurotrophic factor (BDNF) levels, which promote hippocampus plasticity via increased mature BDNF and receptor function.[20,21] Exergame therapy raised BDNF levels and enhanced cognitive function, particularly in the language domain of the MoCA-Ina, with a trend toward better abstraction and memory/delayed recall.[22] BDNF, an important neurotrophin, aids brain development, maintains neuronal health, and promotes synaptic plasticity.[23] Specific modifications in dendritic spines, as well as adult hippocampal neurogenesis, can be connected to different types of learning and memory.[24,25]

The limitations of this study included a primary focus on handgrip strength and cognitive function, without the assessment of biomarkers such as BDNF levels to support the mechanisms underlying the effects of VR sports gaming. This limited the ability to explain the neurophysiological processes contributing to the observed results. Additionally, measurements were taken only over an 8-week period, without assessing long-term outcomes after 3 or 6 months, which limited the understanding of the sustained effects of the intervention over time. The study also involved stroke patients at various stages, without distinguishing between acute, subacute, and chronic phases, which may have introduced variability in recovery potential and responsiveness to the intervention, thereby affecting the consistency of the findings.

CONCLUSION

The combination of conventional rehabilitation and VR exergames is more effective than traditional therapy alone in improving handgrip strength and cognitive function in post-stroke patients. VR exergames enhance both motor and cognitive recovery, making them a valuable addition to rehabilitation. Their integration into clinical practice should consider facility availability, therapist expertise, and patient characteristics. The researchers suggest further examining the treatment effects on neurobiological factors, such as BDNF levels, and determining how the stroke phase influences therapy outcomes, optimal duration, and intensity.

ETHICAL CONSIDERATION

The research was conducted following receipt of ethical clearance from the Ethics Commission of the Faculty of Medicine at Universitas Hasanuddin, under approval number 97/UN4.6.4.5.31/PP36/2025. All patients were educated on the study's aims, procedures, and potential risks and benefits, and they willingly consented to participate by signing a written informed consent form.

CONFLICT OF INTEREST

The authors have declared that they have no conflicts of interest.

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AUTHOR CONTRIBUTIONS

JDW handled data collection, methodological development, and manuscript drafting. RH was responsible for conception, study design, and critical revisions; WOSN, HM, and AAZ contributed to critical revisions. YW conducted data analysis and interpretation. All authors contributed to drafting and approved the final manuscript.

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