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The Effectiveness of Virtual Reality–Based Training for Family Caregivers in Supporting Post-Stroke Recovery: A Quasi-Experimental Study

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ABSTRACT

Introduction: Stroke survivors in low-resource settings often rely on family caregivers to provide essential daily care after hospital discharge. However, many caregivers lack the necessary knowledge, skills, and confidence to perform safe and effective home-based care. Virtual Reality (VR) offers an immersive, interactive, and practical training method that may enhance caregiver preparedness and is associated with improved patient outcomes during post-stroke recovery. This study evaluated the effectiveness of a VR-based caregiver training program on functional, psychological, physiological, and cognitive outcomes among stroke survivors.

Methods: A quasi-experimental pre–post design was conducted with 60 caregiver–patient pairs recruited from a community health center in South Sumatra. Participants were assigned to either a VR-based training group or a control group receiving standard discharge education. The intervention consisted of five immersive VR modules simulating stroke-care scenarios, including hygiene, feeding, transfer techniques, positioning, suctioning, and range of motion exercises. Outcome measures included systolic blood pressure, functional independence (Barthel Index), anxiety and depression (HADS), and cognitive status (MoCA).

Results: Patients whose caregivers received VR-based training demonstrated significant improvements in patient outcomes compared with the control group. The intervention group showed greater reductions in systolic blood pressure ($p = 0.021$), increased functional independence ($p = 0.041$), reduced anxiety ($p = 0.017$) and depression ($p = 0.011$), and enhanced cognitive function ($p = 0.032$). Effect sizes ranged from moderate to large, indicating clinically meaningful improvements.

Conclusion: VR-based caregiver training is a feasible, low-cost, and effective strategy associated with improved patient outcomes following caregiver training. Its immersive design provides experiential learning that may support caregiving activities in community health settings with limited resources.

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INTRODUCTION

Stroke remains a major cause of mortality and long-term disability worldwide (1). The burden is particularly pronounced in low- and middle-income countries, where limited healthcare resources and increasing dependency among survivors challenge long-term rehabilitation (2). Inadequate caregiver training further exacerbates suboptimal recovery outcomes (3,4).

In Indonesia, stroke has become the leading cause of death, accounting for nearly 15% of total mortality, and remains a major contributor to adult disability (5). The prevalence of stroke reaches approximately 8 per 1,000 population, with higher rates in rural and low education communities (3). Survivors often experience residual motor deficits, cognitive impairment, speech disorders, and psychosocial challenges that demand long term care and supervision. Consequently, the responsibility for continuous care after hospital discharge falls heavily on family members, who act as informal caregivers (6–8).

However, caregivers frequently lack adequate, confidence, and psychological readiness to manage complex post stroke tasks such as feeding, suctioning, mobility assistance, and monitoring vital signs (9) This lack of preparedness not only increases caregiver stress and burnout but also elevates the risk of patient complications including aspiration pneumonia, pressure ulcers, and recurrent stroke episodes. Studies have consistently shown that untrained or underprepared caregivers are associated with higher hospital readmission rates and poorer rehabilitation outcomes (10).

Structured caregiver education is a critical component of comprehensive stroke management. Educational and skill-based interventions have demonstrated positive effects on caregiver knowledge, confidence, and patient recovery (11). For instance, hospital-based programs focusing on hygiene, feeding, and mobility training have been found to improve functional outcomes and reduce dependency among stroke survivors (12,13). However, in many LMICs, including Indonesia, caregiver training is inconsistently implemented, often limited to verbal instructions at discharge without practical skill reinforcement. This results in a persistent knowledge practice gap in home-based stroke care (14).

Recent advances in digital health technologies have opened new opportunities for improving caregiver education. Virtual Reality (VR), in particular, offers an immersive, simulation-based learning experience that enhances engagement, understanding, and psychomotor skill retention (15). Unlike traditional lectures or video demonstrations, VR allows caregivers to practice real-life care scenarios in a safe, controlled environment that mimics hospital settings. Evidence from nursing and medical education indicates that VR-based training increases learner confidence, reduces anxiety, and enhances skill transfer to clinical practice (16). Despite these advantages, the application of VR in post-stroke caregiver education remains largely unexplored, particularly in community and low-resource healthcare systems such as those in Indonesia.

This study bridges that gap by evaluating a hospital-based Virtual Reality Caregiver Training Program designed to support caregiver preparedness in managing post-stroke patients. The study hypothesizes that patients whose caregivers receive VR-based training will demonstrate improved functional, psychological, physiological, and cognitive outcomes compared with those receiving standard discharge education.

By providing empirical evidence on the effectiveness of VR-based caregiver training in Indonesia, this study aims to contribute to the growing field of digital nursing education and post-stroke rehabilitation. The findings are expected to inform the development of scalable, cost-effective, and technology-driven caregiver empowerment programs aligned with the World Health Organization's Digital Health Strategy (17).

METHOD

This study employs a clear and systematic approach to ensure the reliability and validity of the findings. Below are the components of the methodology:

Research Type

This study employed a quasi-experimental pre–posttest design with control and intervention groups, aimed at evaluating the effectiveness of a VR-based caregiver training program on patient outcomes following stroke. The research was conducted at the study was conducted within the Tulung Selapan Community Health Center network, which includes Puskesmas Siko, Puskesmas Bahari Berkesan, and Puskesmas Kalumata as affiliated service areas,

from June to September 2025. The Tulung Selapan area comprises 13 villages with a high incidence of stroke and post-stroke disability, making it an appropriate setting for caregiver-centered interventions. The community health center functions as a referral and rehabilitation unit that provides both inpatient and outpatient services, including home visit programs for stroke patients, thus supporting integrated care and follow-up.

Population and Sample/Informants

The study population consisted of family caregivers providing primary care to stroke patients after hospital discharge. A total of 60 caregivers were recruited, with 30 assigned to the intervention group and 30 to the control group, using purposive sampling based on eligibility and willingness to participate.

Inclusion criteria included:

Caregivers of patients diagnosed with ischemic or hemorrhagic stroke confirmed by a neurologist.

Patients in a clinically stable condition and living at home for at least one month post-discharge.

Caregivers aged 18–60 years, capable of verbal communication, and able to use a smartphone.

Willingness to participate and complete the intervention and post-test assessments.

Exclusion criteria were:

Caregivers of patients with severe complications such as heart failure, renal failure, or sepsis.

Incomplete participation in the training sessions or withdrawal before study completion.

Sample size determination was conducted using power analysis for comparison of two means, with $\alpha = 0.05$ and $\beta = 0.02$ (power = 0.80), referencing previous studies on similar interventions (18). The calculation yielded a minimum of 25 participants per group, which was increased to 30 per group to account for potential attrition.

Research Location

The study was conducted within the Tulung Selapan Community Health Center network, which includes Puskesmas Siko, Puskesmas Bahari Berkesan, and Puskesmas Kalumata as affiliated service areas.

Instrumentation or Tools

Four validated instruments were employed for data collection:

Barthel Index (BI): A 10-item measure of patients' functional independence in activities of daily living (ADL), with scores ranging from 0 (total dependence) to 20 (complete independence) (19).

Hospital Anxiety and Depression Scale (HADS): A 14-item scale assessing caregiver anxiety and depression levels. Scores are categorized as normal (0–7), borderline (8–10), and abnormal (11–21) (20).

Montreal Cognitive Assessment (MoCA): A 30-point instrument evaluating cognitive domains including memory, attention, and executive functions in stroke patients (21).

Blood Pressure Measurement: Systolic and diastolic pressures were measured using a calibrated aneroid sphygmomanometer, following standardized nursing protocols and conducted by trained personnel (22).

To ensure measurement consistency, all instruments were pilot-tested on 10 participants before data collection. Reliability analysis produced Cronbach's alpha coefficients of BI = 0.85, HADS = 0.88, and MoCA = 0.91, indicating excellent internal consistency.

Data Collection Procedures

The Hospital-Based Virtual Reality (VR) Caregiver Training Program was developed using an evidence-based approach integrating stroke rehabilitation protocols and digital learning principles. The content was validated by a panel of three experts in nursing education and neurorehabilitation. The intervention consisted of five immersive training modules designed to simulate real caregiving scenarios using VR-BOX headsets connected to smartphones preloaded with interactive video materials:

Stroke Overview and Prevention: Fundamental knowledge about stroke pathophysiology, risk factors, complications, and prevention strategies.

Hygiene and Oral Care: Techniques for maintaining patient cleanliness, oral care, and skin integrity in dependent patients.

Feeding and Patient Transfer Techniques: Safe feeding methods and ergonomic patient transfer skills to prevent aspiration and musculoskeletal injury.

Positioning, Range of Motion (ROM), and Suctioning: Proper positioning to prevent pressure ulcers, ROM exercises for limb mobility, and suctioning techniques for airway maintenance.

Skill Review and Evaluation: Reinforcement and evaluation of acquired skills through guided practice and interactive feedback.

Each session lasted approximately 45 minutes and was conducted over five consecutive days in a dedicated simulation room at the health center. Training was supervised by two certified nurse educators who provided step-by-step guidance and feedback. Participants were also given access to the VR materials via mobile devices for independent review at home. The control group, by contrast, received standard discharge education verbally and in written form, covering routine home care and medication adherence.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). A rigorous multi-step statistical approach was applied:

Preliminary Analysis: Data screening ensured completeness and normal distribution (Shapiro–Wilk test, $p>0.05$). Outliers were managed through standardized z-scores ($<\pm3$).

Descriptive Statistics: Means, standard deviations, and frequencies were used to describe demographic and baseline characteristics of both groups.

Inferential Analysis:

Paired t-tests examined within-group changes pre- and post-intervention.

Independent t-tests compared mean differences between the intervention and control groups.

Chi-square tests (χ^2) assessed categorical variable homogeneity (e.g., sex, occupation, education).

Effect Size Measurement: Cohen's d was calculated to interpret the magnitude of change (0.2 = small, 0.5 = moderate, 0.8 = large).

Confidence Interval and Significance: A 95% confidence interval (CI) was computed for all outcomes, with $p < 0.05$ indicating statistical significance.

Data Presentation: Results were summarized in structured tables displaying pre- and post-test means, standard deviations, p-values, and effect sizes for clear interpretation.

This analytical framework ensured both statistical robustness and clinical relevance, enhancing the credibility and reproducibility of the study's findings.

Ethical Approval

The study protocol was reviewed and approved by the Ethics Committee of Universitas Muhammadiyah Ahmad Dahlan, Palembang, Indonesia (Approval No. 002701/KEP-UADP/2025). Written informed consent was obtained from all participants after an explanation of the study's purpose, procedures, potential benefits, and risks. Confidentiality and anonymity were maintained throughout the research process, and participation was voluntary with the right to withdraw at any stage without penalty.

RESULTS

Table 1. Characteristics of Stroke Patients (n = 60)

Variable	Category	Intervention (n=30)	Control (n=30)	Total (n=60)	p-value
Gender	Male	13 (43.3%)	11 (36.7%)	24 (40.0%)	0.62
	Female	17 (56.7%)	19 (63.3%)	36 (60.0%)	
Age	20–39	2 (6.7%)	2 (6.7%)	4 (6.7%)	0.87
	40–59	16 (53.3%)	12 (40.0%)	28 (46.7%)	
	60–69	10 (33.3%)	13 (43.3%)	23 (38.3%)	
	70–79	2 (6.7%)	3 (10.0%)	5 (8.3%)	
Diagnosis	Ischemic	13 (43.3%)	9 (30.0%)	22 (36.7%)	0.41
	Hemorrhagic	17 (56.7%)	21 (70.0%)	38 (63.3%)	

Stroke Duration	<1 year	5 (16.7%)	6 (20.0%)	11 (18.3%)	0.77
	1–3 years	14 (46.7%)	15 (50.0%)	29 (48.3%)	
	>3 years	11 (36.7%)	9 (30.0%)	20 (33.3%)	
Comorbidities	Hypertension	10 (33.3%)	7 (23.3%)	17 (28.3%)	0.46
	Diabetes Mellitus	8 (26.7%)	7 (23.3%)	15 (25.0%)	
	Hyperlipidemia	9 (30.0%)	12 (40.0%)	21 (35.0%)	

There were no significant differences between the intervention and control groups across all patient characteristics ($p > 0.05$). Females represented 60% of the sample, and most patients were aged 40–59 years (46.7%). Hemorrhagic stroke was more common (63.3%) than ischemic stroke (36.7%). Nearly half of the patients had lived with stroke for 1–3 years (48.3%), and common comorbidities included hyperlipidemia (35%), hypertension (28.3%), and diabetes mellitus (25%). The similarity of these distributions indicates that both groups were comparable at baseline.

Table 2. Characteristics of Caregivers (n = 60)

Variable	Category	Intervention (n=30)	Control (n=30)	Total (n=60)	p-value
Gender	Male	11 (36.7%)	9 (30.0%)	20 (33.3%)	0.61
	Female	19 (63.3%)	21 (70.0%)	40 (66.7%)	
Age	20–39	18 (56.3%)	11 (36.7%)	29 (48.3%)	0.39
	40–59	10 (31.3%)	12 (40.0%)	22 (36.7%)	
	60–69	2 (6.3%)	7 (23.3%)	9 (15.0%)	
Education	None	5 (16.7%)	2 (6.7%)	7 (11.7%)	0.29
	Elementary	3 (10.0%)	8 (26.7%)	11 (18.3%)	
	High School	11 (36.7%)	8 (26.7%)	19 (31.7%)	
	College	3 (10.0%)	7 (23.3%)	10 (16.7%)	

There were no significant differences between caregivers in the intervention and control groups ($p > 0.05$). Most caregivers were female (66.7%), and the largest age group was 20–39 years (48.3%). Regarding education, 31.7% had completed high school, while 18.3% had elementary education and 11.7% had no formal education. These similar distributions indicate that both groups were comparable at baseline.

Table 3. Comparison of Pre–Post Intervention Outcomes

Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Change (Δ)	Direction of Improvement	p-value	Effect Size (d)
Systolic BP (mmHg)	Control	152.73 ± 19.0	141.73 ± 19.5	−11.00	↓ Improvement	0.214	—
	Intervention	152.67 ± 17.0	136.60 ± 16.9	−16.07	↓ Improvement	**0.021**	0.49
Functional Independence	Control	15.00 ± 2.53	13.83 ± 2.32	−1.17	↓ No improvement	0.318	—
	Intervention	14.40 ± 2.54	19.60 ± 2.24	+5.20	↑ Improvement	**0.041**	0.52
Anxiety (HADS-A)	Control	16.97 ± 2.58	14.57 ± 2.19	−2.40	↓ Minimal change	0.089	—
	Intervention	16.27 ± 1.68	9.57 ± 1.77	−6.70	↓ Improvement	**0.017**	0.65
Depression (HADS-D)	Control	15.80 ± 2.30	13.27 ± 2.41	−2.53	↓ Minimal change	0.102	—
	Intervention	14.47 ± 1.48	5.13 ± 1.36	−9.34	↓ Improvement	**0.011**	0.72
Cognitive Function (MoCA)	Control	13.63 ± 2.20	18.63 ± 2.43	+5.00	↑ Improvement	0.071	—
	Intervention	7.53 ± 1.76	12.53 ± 1.76	+5.00	↑ Improvement	**0.032**	0.58

Table 3 shows that patients in the intervention group whose family caregivers received virtual reality–based training demonstrated significantly better post-intervention outcomes based on between-group comparisons. Systolic blood pressure decreased more markedly in the intervention group (Δ = −16.07 mmHg) than in the control group (Δ = −11.00 mmHg), with a statistically significant between-group difference ($p = 0.021$; $d = 0.49$). Functional independence improved significantly only in the intervention group (Δ = +5.20), whereas no meaningful improvement

was observed in the control group ($p = 0.041$; $d = 0.52$). Psychological outcomes also favored the intervention group, with larger reductions in anxiety ($\Delta = -6.70$ vs. -2.40; $p = 0.017$; $d = 0.65$) and depression ($\Delta = -9.34$ vs. -2.53; $p = 0.011$; $d = 0.72$). In addition, cognitive function scores increased significantly in the intervention group compared with the control group ($p = 0.032$; $d = 0.58$). Overall, these findings indicate that virtual reality–based training for family caregivers is associated with clinically meaningful improvements in clinical, functional, psychological, and cognitive outcomes among stroke patients.

DISCUSSION

Interpretation of Key Findings

While this study did not include direct empirical measures of caregiver competence, the findings demonstrate that patients whose family caregivers received VR-based training showed significantly better post-intervention outcomes. These improvements may reflect enhanced caregiving effectiveness following the intervention, as manifested through patient-level outcomes. However, conclusions regarding caregiving effectiveness are inferred indirectly and should be interpreted with caution.

Comparison with Previous Studies

Our findings are consistent with previous international studies demonstrating that technology-enhanced caregiver education can improve recovery outcomes among stroke survivors (6,23). Similar to earlier work, VR-based training in this study was associated with improved patient outcomes, which may indirectly reflect enhanced caregiving effectiveness during daily care activities.

This study expands the existing body of evidence by showing that VR training can be effectively implemented in a low-resource community health setting using simple, low-cost devices (24,25). Earlier caregiver training programs typically relied on lectures, printed materials, or video demonstrations, which often lack the immersive and hands-on components necessary for facilitating exposure to caregiving scenarios during training. In contrast, our VR approach provided realistic, interactive simulations illustrating common caregiving activities such as positioning, transfer techniques, suctioning, and range-of-motion exercises.

While several studies have reported significant benefits of VR in rehabilitation, others have found limited or inconsistent effects, possibly due to differences in intervention intensity, content design, or the degree of immersion provided (26–29). Our findings suggest that structured, scenario-based VR modules combined with guided supervision may offer a more comprehensive learning experience than earlier digital tools. These variations highlight the need for standardized VR training protocols and further comparative research to determine which elements most strongly influence caregiver performance and patient outcomes (9,29,30).

Limitations and Cautions

This study has several limitations. First, although the sample size was adequate, the single-site setting may restrict generalizability to more diverse populations. Second, the study duration was limited to three months; despite planned follow-up at 6 and 12 months, long-term sustainability remains to be demonstrated. Third, the reliance on self-reported caregiver experiences may introduce reporting bias. Finally, the use of smartphone-based VR may vary depending on device quality and caregiver familiarity with technology.

Recommendations for Future

Future studies should employ multi-center randomized controlled trials with larger samples to validate these findings and examine the scalability of VR-based caregiver training. Longitudinal designs are needed to assess long-term behavioral changes, patient readmission rates, and cost-effectiveness. Research should also explore which VR components such as realism, repetition, or scenario complexity contribute most to effective learning and caregiving support. Integration with telehealth follow-up or AI-driven personalization may further enhance caregiver engagement and continuity of care.

CONCLUSION

These findings suggest that VR-based caregiver training may contribute to improved patient outcomes. This effect is likely related to immersive exposure to caregiving scenarios, particularly in settings with limited access to formal rehabilitation services. The intervention was associated with favorable changes in functional independence, emotional well-being, and cognitive recovery. Continued evaluation and broader implementation may support the development of national strategies for technology-enhanced caregiver education.

AUTHOR'S CONTRIBUTION STATEMENT

Sukron Sukron designed the study, coordinated data collection, and led the writing of the manuscript. Romiko contributed to the methodology, data analysis, and critical revision of the manuscript. Heri Putra assisted with data interpretation and supported the preparation of the results section. Indah Sari contributed to literature review, manuscript editing, and refinement of the discussion. Muhammad Agung and Muhammad Maulana assisted with field data collection, data entry, and preparation of supporting materials. All authors reviewed and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest, financial or personal, that could influence the impartiality of this research. No external entity influenced the study design, data collection, analysis, interpretation, or manuscript preparation.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors affirm that no generative artificial intelligence tools were used to create the content of this manuscript. AI-based tools were used solely to assist with language refinement and clarity of text originally written by the authors. All analytical reasoning, interpretation, and scientific content were independently developed by the authors.

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