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Immersive Virtual Reality-based Rehabilitation for Upper Limb Recovery in Early Stroke Patients: A Feasibility Study

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INTRODUCTION

Stroke is a major cause of death and long-term disability, with **80%** of survivors experiencing significant upper limb **(UL) motor impairments** that hinder daily activities and decrease quality of life[1]. Recovery of UL function, crucial for independence, depends on **neuroplasticity**, particularly during the **early stages post-stroke** when the brain's capacity for reorganization is highest.

Conventional rehabilitation (CR) therapies often **lack the intensity** needed for effective recovery. In contrast, virtual reality (**VR) rehabilitation** allows for **higher doses** of repetitive **motor training and exploration**, essential for enhancing neuroplasticity and improving motor functions[2]. Immersive VR further enhances these benefits by providing **engaging, three-dimensional** environments with **real-time feedback, tailored to individual needs**[3]. Despite its effectiveness and safety, immersive VR faces challenges like the need for specialized training and adaptations for severely impaired patients, but its personalized, resource-efficient approach shows significant potential for early post-stroke rehabilitation.

AIM

This study aims to evaluate the: **feasibility** and **dose-response** of Immersive VR-based rehabilitation for UL recovery in acute and subacute stroke patients.

METHOD

A pilot trial included 12 early-stage stroke patients **randomized** into two groups:

- Group A (10 IVR sessions + CR), and
- Group B (20 IVR sessions + CR).

IVR Rehabilitation Protocol (Figure 1)**:**
Daily sessions (20–30 min) using *Kinesix XR* (Neuro Group XR Inc., Montreal, Canada).
Structure: (1) Motor assessment; (2) Exploratory movements & mirror therapy; (3) Reach and grasp training; (4) Fine motor control tasks; (5) Simulated Activities of Daily Living (ADLs); (6) 360° Gym immersive training.

Feasibility outcomes included adherence, usability (User Satisfaction Evaluation Questionnaire [USEQ], System Usability Scale [SUS]), system operability, and adverse effects.

Motor outcomes, categorized by the International Classification of Functioning, Disability, and Health, assessed impairment (Fugl-Meyer Assessment [FMA-UE], Medical Research Council scale [MRC]), activity (Box and Block Test [BBT]), and participation (Motor Activity Log 30 [MAL]).
Blinded therapists conducted assessments at baseline, post-intervention, and 4-week follow-up.

Dose-response was analyzed using Probability of Superiority (PS).

RESULTS

Figure 1. Intervention: Early stroke patients engaging with Kinesix XR. (A) Early stroke patients using the system, (B) motor exploration exercises, (C) task-oriented training, and (D) simulations of activities of daily living.



(A) (B) (C) (D)

Participant Characteristics

• Number of participants:	12 (Group A=6, B=6)
• Between-group differences:	No significant
• Mean age:	59.8 ± 14.2 years
• Stroke type:	83% ischemic stroke
• Stroke severity:	Moderate to severe
• Upper limb impairmet:	Moderate to severe
• Stroke phase:	Early (acute-subacute)

Feasibility was high

• Adherence (180/184):	98%
• Usability Patient (USEQ):	81.6 ± 15%
• Usability Therapist (SUS):	77.5 ± 7.4%
• System Initial Setup:	5.14 ± 1.57 min
• System Stability:	77.86 ± 6.78%
• No severe adverse effects:	2 visual discomfort

Motor Effects were significats (Table 1)	Within-group changes Post-hoc significance
Dose-Response higher in (Table 2)	Group B (20 sessions)
• Probability of Superiority:	75–88%
• MCID/MDC Exceeded in:	B: FMA-UE, MAL A &Q A: BBT (only MDC)

Table 2. Dose-Response Comparison Between Groups

Outcome Measure	Minimal Detectable Change	Median Change (Group A)	Median Change (Group B)	p-value (A vs B)	PS (B superior)
FMA UE	5.2	+17	+23	0.630	80.0%
MRC	N/A	+3.5	+3.5	0.142	75.0%
BBT Affected	5.5	+7	+4.5	0.294	76.0%
BBT Unaffected	N/A	+12	+4	0.335	85.0%
MAL Amount	0.56-1.06	+0.7	+1.5	0.196	88.0%
MAL Quality	0.56-1.06	+0.55	+1.7	0.333	86.0%

Note: Median change reflects the difference between pre and post-intervention in each group. p-values were calculated using the Mann-Whitney U test for between-group comparisons, while the Probability of Superiority (PS) represents the likelihood that a randomly selected score from Group B will be superior to one from Group A. N/A= lack of an established MDC; FMA UE= Fugl-Meyer Assessment; MRC= Medical Research Council Scale; BBT= Box and Block Test; MAL= Motor Activity Log.

Table 1. Motor Effects Summary

ICF Domain	Measure	Improvement ($p < 0.05$)	Sustained at Follow-up	Group B Superiority (PS)	MCID/MDC Exceeded
Impairment	FMA-UE	✅	✅	80%	✅ Group B
	MRC	✅	✅	75%	⚠
Activity	BBT Affected Side	✅	✅	76%	✅ Group A (MDC only)
	BBT Non-Affected Side	✅	❌	85%	⚠
Participation	MAL Amount	✅	✅	88%	✅ Group B
	MAL Quality	✅	✅	86%	✅ Group B

Note: Friedman's ANOVA for within-group comparisons; Wilcoxon Signed-Rank Test (with Bonferroni correction) for post-hoc analysis. ✅ = Statistically significant or exceeded threshold; ⚠ = No MCID/MDC available. PS= Probability of Superiority; MCID= Minimal Clinically Important Difference; MDC= Minimal Detectable Change.

CONCLUSIONS

IVR-based rehabilitation showed high feasibility, safety, and functional benefits with a dose-response trend.
Larger studies are needed to confirm efficacy.

CONTACT INFORMATION

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