Case Series

Virtual At-Home Therapy for Upper Limb Rehabilitation Post-Stroke

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NEUROFENIX

Abstract

Research Objective: To evaluate the effectiveness of a 16-week high-intensity virtual at-home therapy program integrating Occupational Therapy, Rehabilitation Technology, and remote monitoring in improving functional outcomes for post-stroke patients.

Introduction/Background: Stroke is a leading cause of long-term disability, with 40% to 80% of survivors experiencing upper limb dysfunction. Recovery often depends on access to high-dose rehabilitation, but many patients face barriers, such as mobility challenges, transportation, and limited resources. Virtual rehabilitation programs aim to overcome these obstacles by providing accessible, cost-effective therapy comparable to traditional in-clinic care.

Design: Case Series

Setting: At-home therapy with an Occupational Therapist through a virtual platform.

Participants: This case series examined eight patients, 2 to 21 years post-stroke, aged 29 to 70 years. Among them, 37.5% had left-side involvement, and 62.5% had right-side involvement. Stroke types included hemorrhagic (50%), ischemic (25%), and unspecified (25%).

Intervention/Method: Following a comprehensive evaluation, patients participated in a 16-week virtual upper limb stroke program using the NeuroBall Platform and attended weekly one-on-one virtual therapy sessions. A personalized therapy plan was prescribed weekly, integrating the NeuroBall Platform, therapeutic exercises, and task-specific training for activities of daily living (ADLs). The virtual therapist provided ongoing remote therapeutic monitoring (RTM) to track patient adherence, communicated weekly to review progress, provide support and motivation, and adjust the plan as needed.

Main Outcome Measures: Patient adherence, Modified Rankin Scale, Pain and Fatigue Visual Analog Scales (VAS), EQ5D, Overall Health Score, Functional Upper Extremity Level (FUEL), Range of motion (ROM), Stroke impact scale- hand function, Motor Activity Log (MAL) for amount of use (AOU) and quality of movement (QOM), ADL functional status and goal setting.

Results: Significant improvements in AROM and functional Activities of Daily Living (ADL) performance were observed, with adherence rates exceeding 90% and notable gains in SIS and MAL scores. Wilcoxon signed-rank tests indicated statistically significant gains in AROM ($p = 0.000976$). A strong positive correlation ($r = 0.96$) was observed between adherence and functional outcomes, highlighting the critical role of patient engagement. Improvements were also assessed through clinical interpretation, linking gains in mobility to improved ADLs and independence.

Conclusion: The statistical analysis demonstrates significant improvements in multiple domains, including fine motor control, independence in ADLs, and upper limb functionality following the 16-week virtual Upper Limb Stroke Program. These findings suggest that virtual rehabilitation using the NeuroPlatform can be an effective intervention for improving motor function and daily living activities in stroke survivors in the chronic phase of stroke.

Keywords: Stroke Rehabilitation, Occupational Therapy, Upper Extremity, Virtual therapy, At-home therapy, NeuroRehab, Remote Therapeutic Monitoring, Digital Health Technology

Introduction/Background

Stroke is a leading cause of long-term disability (CDC, 2023), with 40 to 80% of survivors experiencing upper limb dysfunction (Simpson et al, 2021, Hayward et al, 2021). Paresis, the most common post-stroke impairment, ranging from mild weakness to complete paralysis (Lang et al., 2013). Effective recovery relies on high-dose rehabilitation, such as physical and occupational therapy, but access and adherence are often hindered by mobility challenges, transportation barriers, and limited resources (Knepley et al., 2021; Cramer et al., 2021).

These barriers are particularly concerning, as approximately 60% of patients with nonfunctional upper limb function one week post-stroke remain impaired after six months, transitioning to chronic stroke (Harvey, 2015). However, research demonstrates that chronic stroke survivors can still achieve meaningful improvements in daily living activities, even years after their stroke (Rubio Ballester et al., 2019).

Virtual rehabilitation programs address these challenges by providing accessible, cost-effective, and personalized therapy directly to patients' homes. These programs have been shown to deliver functional gains in upper limb recovery and high patient satisfaction,

Evaluation

Initial Assessment

Patients underwent baseline evaluations and monthly re-assessments, including:

- **Active Range of Motion (AROM):** Shoulder flexion, shoulder abduction, external rotation, elbow flexion, elbow extension, supination, pronation, wrist flexion/extension, finger flexion/extension.
- **Passive Range of Motion (PROM):** Shoulder flexion, shoulder abduction, external rotation, elbow flexion, elbow extension, supination, pronation, wrist flexion/extension, finger flexion/extension.
- **Functional Assessments:**
  - Modified Rankin Scale (mRS)
  - Pain and Fatigue scales (0-10)
  - Patient Health Questionnaire (PHQ-2)
  - EQ-5D health status questionnaire
  - Stroke Impact Scale (SIS) - Hand function
  - Motor Activity Log (MAL) for Amount of Use and Quality of Movement
  - Functional Upper Extremity Level (FUEL)
- **Goal Achievement** (Noted at re-assessments)
- **Adherence** (Noted at re-assessments)

Goal Setting

Individualized therapy goals were established, including:

- Increased ROM and strength to perform activities of daily living (ADLs)
- Independent self-care, grooming, and meal preparation
- Participation in community activities

Intervention

Comprehensive
Initial Evaluation

Patient Onboarding
to familiarize with technology and program protocols

Virtual Therapy
16-week virtual therapy sessions led by licensed therapists

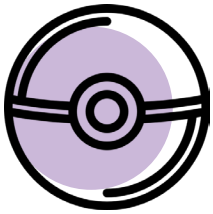
3 Re-assessments
to monitor progress and adjust therapy plans as appropriate

Discharge Evaluation
to assess outcomes and goals achieved

Personalized Weekly Home-based Therapy Plan

- Home-based therapy plan
- ADL-Specific activities tailored to individual goals - 75 mintues per week
- Therapeutic Exercises

Therapeutic Activities Using the NeuroPlatform



5 Days
per week

400 Repetitions
per Session

60 minutes
per Session

Patients were provided with remote monitoring to track adherence to the program and weekly communication and support through phone calls, text messages, and emails providing support, encouragement, and necessary adjustments to the therapy plan.

Results/Data Analysis

1. Active Range of Motion (AROM)

Wilcoxon Signed-Rank Test Results:

- **Test Statistic:** 0.0
- **p-value:** 0.000976 (**significant**)

Explanation: The significant p-value indicates that post-intervention improvements in AROM were meaningful. Percentage gains ranged from 50% to 700% across different joints, demonstrating clinically significant improvements in mobility. Clinically, improvements in shoulder and elbow movements were linked to better performance in ADLs, including dressing, grooming, and meal preparation. See Figure 1.

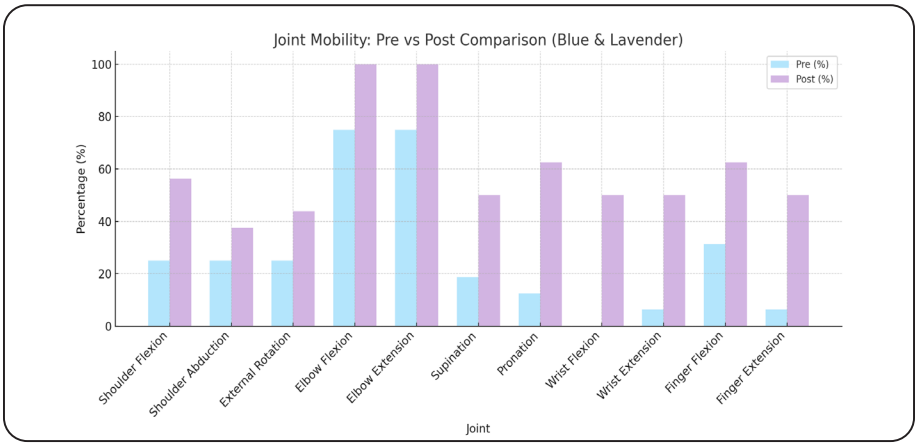


Figure 1. Joint Mobility Pre- and Post-Intervention (AROM)

2. Passive Range of Motion (PROM)

Wilcoxon Signed-Rank Test Results:

- **Test Statistic:** 0.0
- **p-value:** 0.317 (not significant)

Explanation: The PROM results indicate no statistically significant improvements, with only minor changes observed in shoulder flexion (+16.7%). This outcome aligns with expectations, as PROM typically has less room for improvement. Clinically, maintaining full PROM is crucial for preventing stiffness and enabling gains in AROM. See Figure 2.

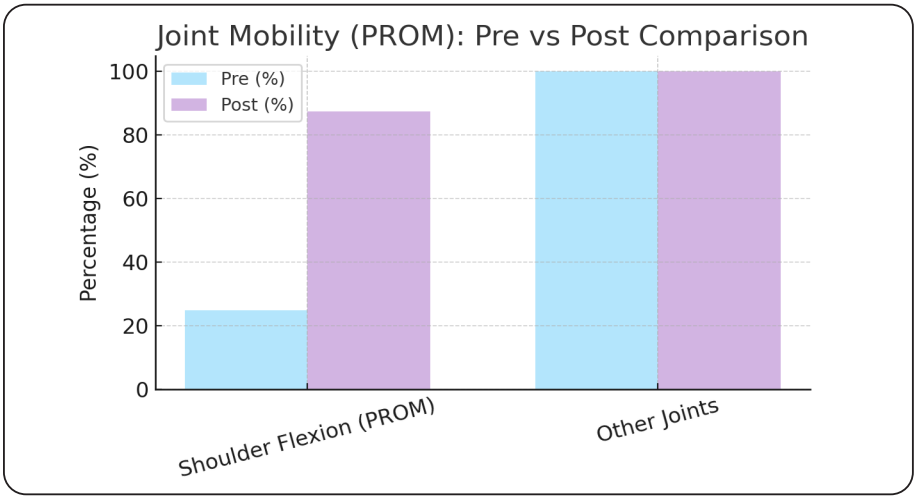


Figure 2. Passive Range of Motion (PROM): Pre- and Post-Intervention Comparison

3. Stroke Impact Scale (SIS - Hand)

Wilcoxon Signed-Rank Test Results:

- **Test Statistic:** 0.0
- **p-value:** 1.0 (not significant)

Explanation: Despite a lack of statistical significance, the 80% improvement in SIS scores reflects meaningful functional recovery. Clinically, this improvement correlates with increased independence in activities requiring fine motor control, such as buttoning clothes and holding utensils. See Figue 3.

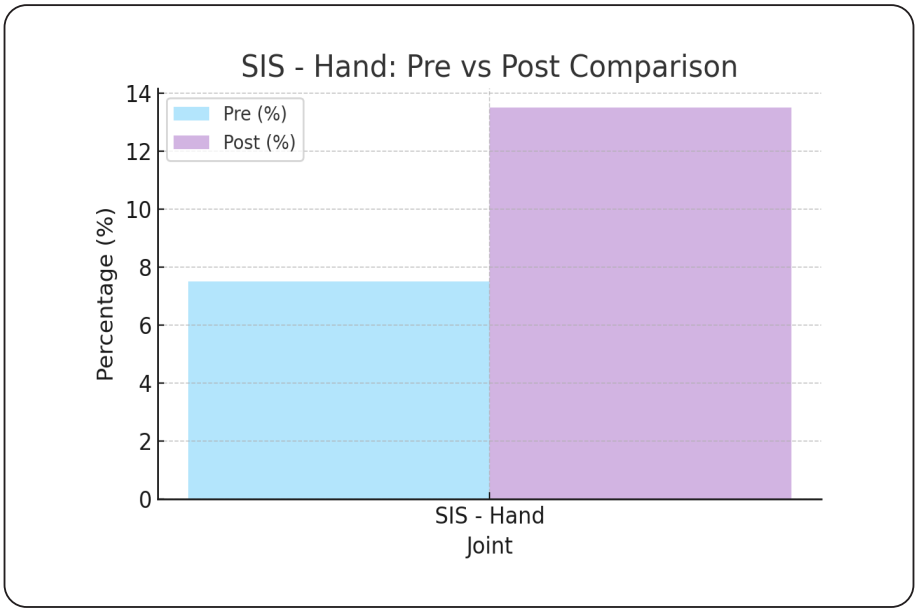


Figure 3. Stroke Impact Scale (SIS - Hand): Pre- and Post-Intervention Comparison

4. Motor Activity Log (MAL)

Wilcoxon Signed-Rank Test Results:

- **MAL-AOU Test Statistic:** 0.0 (p = 1.0)
- **MAL-QOM Test Statistic:** 0.0 (p = 1.0)

Explanation: Although the improvements in both the Amount of Use (AOU) and Quality of Movement (QOM) were not statistically significant (Wilcoxon Signed-Rank Test Statistic = 0.0, p = 1.0), they were clinically meaningful, with mean percentage gains of 330% and 289.5%, respectively. The lack of statistical significance is likely attributed to the small sample size (n=8) and the uniform direction and magnitude of improvement across all participants, which limits the variability needed for the Wilcoxon test to detect significance. Importantly, the consistent and substantial gains in both AOU and QOM reflect enhanced use and control of the affected limb in real-world tasks, underscoring the clinical impact of the intervention despite the statistical limitations. See Figure 4.

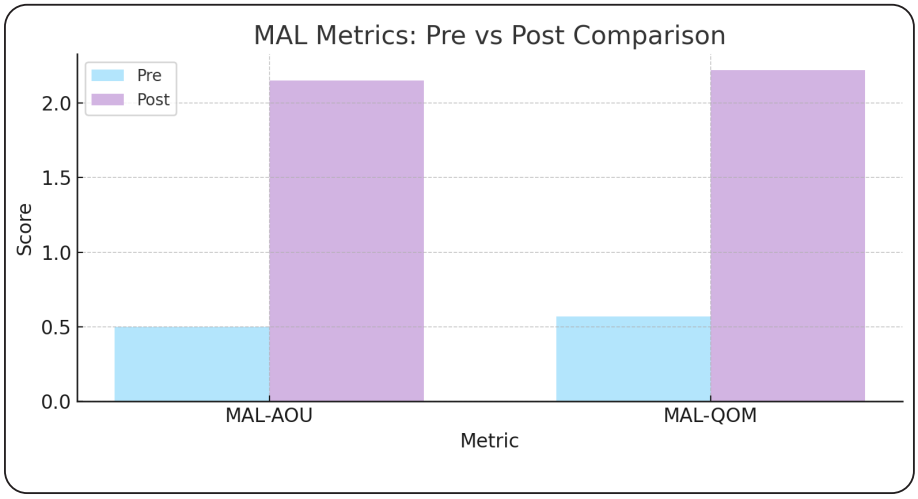


Figure 4. Motor Activity Log (MAL): Pre- and Post-Intervention Comparison

5. Functional Upper Extremity Levels (FUEL)

Explanation: The Functional Upper Extremity Level (FUEL) score increased from 2.5 prior to the intervention to 4.0 following the intervention, reflecting an absolute improvement of 1.5 points and a 60 percent increase. This quantitative gain represents a substantial enhancement in upper extremity function. Qualitatively, the improvement suggests a progression from limited or assisted movement to more active and independent use of the affected limb. This level of functional recovery is associated with greater motor control and strength, supporting the effectiveness of the intervention in promoting meaningful neurological and functional improvements. The observed change in FUEL score highlights the clinical relevance of the program in supporting upper extremity rehabilitation. See Figure5.

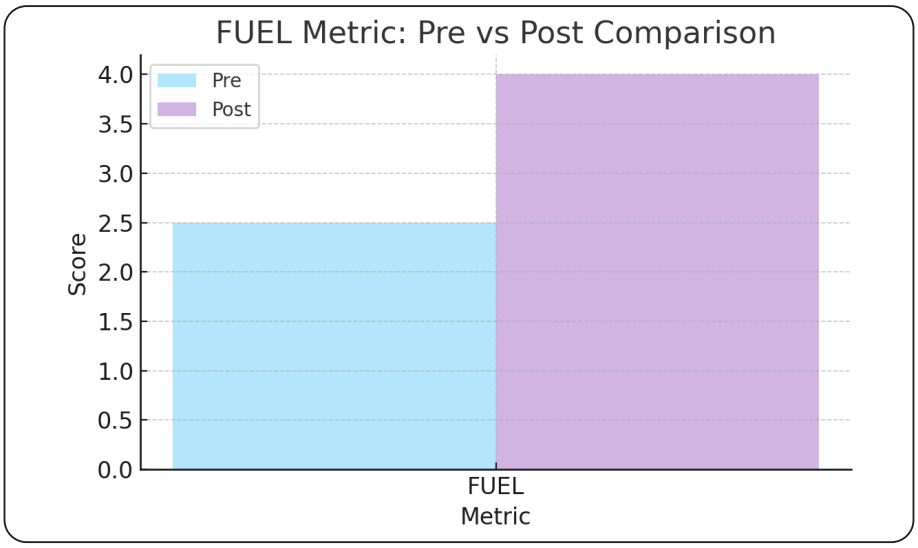


Figure 5. Functional Upper Extremity Levels (FUEL): Pre- and Post-Intervention Comparison

6.Overall Health Score

Explanation: The median overall health score improved from 70 at the initial evaluation to 80 at the 16-week mark, reflecting a 14.3 percent increase. This change in the median score indicates a consistent and meaningful improvement in overall health across the patient population over the course of the intervention. As the median represents the midpoint of all recorded scores, the increase suggests that at least half of the participants experienced notable progress, supporting the effectiveness of the program in delivering broad-based health benefits. This upward trend in the median score serves as a strong indicator of general positive response to the intervention and reinforces its potential value in clinical application. See Figure 6.

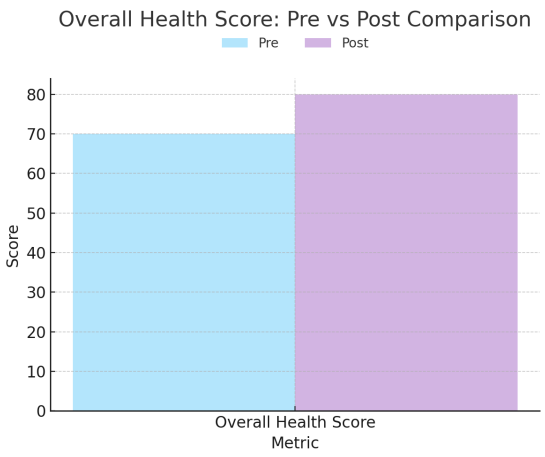


Figure 6. Overall Health Score: Pre- and Post-Intervention Comparison

Statistical Methods and Selection of Outcome Measures

Wilcoxon Signed-Rank Test: The Wilcoxon signed-rank test is a non-parametric statistical test used to compare two related samples, such as pre- and post-intervention measures. It evaluates whether the median difference between paired observations is zero, making it appropriate for small sample sizes and non-normally distributed data, as seen in this case series.

This test was selected because the patient sample size was small (n = 8), and the distribution of the outcome measures did not meet the assumption of normality required for parametric tests, such as paired t-tests. The Wilcoxon signed-rank test provided a robust method to detect significant changes in functional outcomes.

Quantitative vs. Qualitative Measures:

- **Quantitative Measures:** Quantitative measures, such as AROM, PROM, SIS scores, and MAL metrics, provided objective data to track improvements in motor performance and functional independence. These measures were essential to detect statistically significant changes and calculate effect sizes that support clinical conclusions.
  - **Why used:** They allowed for precise tracking of changes and comparisons between baseline and post-intervention outcomes.
- **Qualitative Measures:** Qualitative outcomes, including patient-reported improvements, therapist observations, and FUEL assessments, captured the meaningful context behind numerical gains. For example, observing a patient progress from needing assistance with dressing to performing tasks independently provided valuable insight into real-world functional recovery.
  - **Why used:** They offered a holistic view of recovery, complementing quantitative results by demonstrating the impact of rehabilitation on quality of life and independence.

Goals Achieved

All patients, 8 out of 8 participants, demonstrated significant functional gains and met goals in the following areas: self-care, IADLs, mobility, and leisure tasks. Notable progress was observed in fine motor skills, including improved finger flexion, grip strength and dexterity. Pain and fatigue levels decreased allowing for greater engagement in meaningful activities. These improvements highlight the impact of targeted therapy interventions on functional independence and quality of life.

Self-Care & Personal Hygiene

- Washing hair and body
- Dressing upper and lower body
- Personal hygiene
- Brush Hair and hold a blow dryer

Fine Motor Skills & Dexterity

- Baiting a hook
- Holding a guitar
- Buttoning a shirt
- Cutting food and using utensils
- Opening containers and packages

Leisure Participation

- Praying the rosary
- Hugging loved ones
- Clapping for children
- Writing letters and grocery lists

Household Tasks & Instrumental Activities

- Meal preparation
- Turning on light switches
- Opening doors
- Handling steering wheels
- Making a bed

Improved Movement Patterns

- Improved Range of motion in multiple upper limb pivots
- Reduction in compensatory movement patterns with ambulation (e.g., excessive tone pulling arm to chest)
- Enhanced mobility and posture control

Adherence

- **Median days completed:** 4.9 days a week (78.5 days overall)
  - 98% recommended adherence
- **Median repetitions per session:** 787 reps (total 61,746 reps)
  - 171% recommended adherence
- **Median session duration:** 52.6 minutes a session (total 68.5 hours)
  - 86% recommended adherence
- **Median ADL duration**: 2.6 hours a week (total 42.5 hours)
  - 212% recommended adherence

Implementation Learnings and Continuous Improvement

Throughout the program, a few operational and technical challenges emerged, providing valuable insights to enhance service delivery. Weather-related disruptions briefly impacted Wi-Fi connectivity, prompting a smooth transition to tablet-free exercise sessions. Minor software bugs and sensor issues were promptly resolved by the support team, ensuring continued patient engagement. A couple of patients required additional wrist strapping due to high usage, and one received a replacement NeuroBall to address connection inconsistencies. Another participant needed occasional recalibration for shoulder positioning, highlighting the system's adaptability to varied user needs. These experiences demonstrate both the robustness of the program and the responsiveness of the team to maintain continuity of care.

Patient Feedback:

"Having an app available at all times allows me to balance therapy with my daily activities. It has been easy to use and provides guidance to achieve daily goals." - Patient 1

"I can physically see and feel the improvement-it's encouraging to keep fighting." - Patient 1

"I didn't know I could do this much with my hand after 21 years." - Patient 2

“Structured program with great therapist guidance and support.” - Patient 3

“A friend I don’t see all of the time immediately noticed I was having more functional use of my arm/ hand. - Patient 4

“Neurofenix is a unique program that allows for you to have occupational therapy from the comfort of your own home and on your own time. The program is a combination of hands on and technology.” - Patient 4

Conclusion

This case series highlights the feasibility and clinical value of a 16-week high-intensity virtual at-home therapy program delivered through the NeuroPlatform, which integrates Occupational Therapy, advanced Rehabilitation Technology, and remote monitoring. Participants—all chronic stroke survivors—demonstrated high adherence and engagement, leading to statistically significant improvements in active range of motion (AROM) and clinically meaningful gains in fine motor control, upper limb function, and independence in Activities of Daily Living (ADLs).

These findings underscore the potential for continued neuroplasticity and functional recovery, even in the chronic phase of stroke. They also reinforce the ability of virtual rehabilitation platforms like the NeuroPlatform to expand access to care and support impactful, sustained recovery for individuals living with chronic stroke.

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