# ADVANCED STROKE UPPER EXTREMITY PROGRAM (ASUP) DURING INPATIENT STROKE REHABILITATION: A RANDOMIZED CONTROL STUDY

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## ABSTRACT

Background: Stroke-induced upper extremity impairment is a significant cause of disability, affecting daily activities and quality of life. The Advanced Stroke Upper Extremity Program (ASUP) has been developed to address these deficits through intensive, robot-assisted rehabilitation designed to leverage neuroplasticity for functional recovery.
Methods: In a randomized control trial at the a rehabilitation facility in Qatar, 30 stroke inpatients were allocated to either a control group receiving standard therapy or an experimental group receiving standard therapy supplemented with ASUP. The Action Research Arm Test (ARAT) was employed to evaluate upper limb function both pre- and post-intervention. Analysis included paired and independent t-tests to compare intragroup and intergroup improvements.
Results: Initial assessments revealed considerable upper limb dysfunction in both groups, with mean ARAT scores of 3.85 and 4.14 for the control and experimental groups, respectively. Post-intervention, both groups exhibited improvements in ARAT scores; the control group's mean score increased to 23.21, while the experimental group's mean score rose to 31.43. However, statistical analysis indicated no significant difference between the improvements in the control and experimental groups ($p=0.148$).
Discussion: The study findings align with existing literature that suggests benefits from robot-assisted therapy (Meyer et al., 2021; Platz, 2021; Tadi and Lui, 2022), yet do not conclusively support the superiority of ASUP over traditional therapy methods.
Conclusion: While the ASUP appears to be a promising adjunct to conventional stroke rehabilitation for improving upper limb function, the study did not find a statistically significant difference between the experimental and control groups. Further research with larger sample sizes and longer follow-up is warranted to determine the full impact of ASUP on functional recovery after stroke.

**Keywords:** Stroke Rehabilitation, Upper Extremity, Neuroplasticity, Robot-Assisted Therapy, Randomized Control Trial

## INTRODUCTION

Stroke is a leading cause of long-term disability worldwide, often resulting in significant impairments in upper limb function that adversely impact activities of daily living and overall quality of life. The disruption of cerebral blood flow during a stroke event leads to neuronal damage, which manifests as a loss of motor control, dexterity, and sensory perception, particularly in the upper extremities (Tadi and Lui, 2022). Recovery and rehabilitation thus become pivotal in the stroke survivor's journey towards regaining independence and functionality. Recent decades have seen a surge in rehabilitation techniques supported by growing evidence of the brain's capacity for neuroplasticity, which allows for functional reorganization after injury (Platz, 2021). Robotic-assisted therapies, in particular, have become increasingly prevalent as a means to provide high-dosage and high-intensity task-

specific training, essential for harnessing this neuroplastic potential (Meyer et al., 2021). The integration of robotic systems into rehabilitation programs is premised on their ability to offer consistent and repetitive movement practice, which is crucial for inducing neuroplastic changes (Coscia et al., 2019). Despite advancements in rehabilitative strategies, there remains a gap between the potential of robotic-assisted therapies and their efficacy as indicated by clinical outcomes. This discrepancy underscores the need for well-structured, evidence-based interventions that not only exploit the principles of neuroplasticity but also align with the patients' individual rehabilitation needs (Rodgers et al., 2019). The Advanced Stroke Upper Extremity Program (ASUP) represents an innovative approach within this domain, purportedly combining the benefits of robot-assisted therapy with tailored rehabilitation protocols to maximize recovery of upper limb function.

The purpose of this randomized control study is to critically evaluate the efficacy of ASUP within the context of inpatient stroke rehabilitation. By doing so, the study aims to contribute to the existing body of knowledge regarding stroke rehabilitation, provide evidence for the adoption of ASUP in clinical practice, and ultimately, improve the standard of patient care. This investigation will focus on comparing the functional outcomes of upper extremity motor performance between patients undergoing standard rehabilitation and those participating in the ASUP, utilizing the Action Research Arm Test (ARAT) as a measure of functional improvement. Through rigorous evaluation, this study seeks to elucidate the impact of ASUP on recovery trajectories and inform future clinical pathways.

## LITERATURE REVIEW

The integration of robotic assistance in stroke rehabilitation is an evolving field aimed at harnessing the brain's capacity for neuroplasticity to improve motor function in the affected upper extremity. A concise review of recent literature highlights several key findings and methodologies within this area. Meyer et al. (2021) conducted a pilot randomized controlled trial on the effectiveness of Arm-Hand Boost Therapy during inpatient stroke rehabilitation. The study emphasized the potential of targeted, intensive therapy regimens in enhancing the functional outcomes of stroke patients, suggesting that tailored, high-frequency interventions may accelerate recovery by promoting neuroplasticity. Supporting this, Rodgers et al. (2019) in their multicenter randomized controlled trial, Robot Assisted Training for the Upper Limb After Stroke (RATULS), evaluated the efficacy of robotic interventions compared to conventional therapy. Their findings indicated improvements in motor function but stopped short of establishing robotic therapy as unequivocally superior, calling for further research to optimize these interventions for individual patient needs.

Similarly, Bertani et al. (2017) provided a systematic review with meta-analysis on the effects of robot-assisted upper limb rehabilitation, corroborating the positive outcomes observed in individual patient studies. Their review concluded that robot-assisted therapy could contribute beneficially to the recovery process, albeit with varying degrees of efficacy across different patient demographics. The study by Singh et al. (2021) expanded on this knowledge base, presenting evidence of neuroplasticity with the use of a robotic hand exoskeleton for post-stroke rehabilitation. The controlled trial demonstrated measurable improvements in motor recovery, adding to the body of evidence that suggests robotic technology has a place in modern rehabilitative practices. Clark et al. (2019) explored the role of high-dose task practice in stroke rehabilitation. The paper suggested that a higher intensity of task-specific training could be a critical factor in recovery, advocating for therapies that include such elements, potentially enhanced by robotic assistance.

In line with these findings, Coscia et al. (2019) analyzed the impact of robot-assisted therapy alongside traditional rehabilitative training, noting significant improvements in motor recovery post-stroke. Their work supported the notion that integrating technology into rehabilitation could lead to better functional outcomes. Platz (2019) offered an international perspective on evidence-based guidelines and clinical pathways in stroke rehabilitation, which included robotic therapy as a promising adjunct to enhance motor skill reacquisition in stroke patients. Finally, Tadi & Lui (2022) provided a comprehensive overview of acute stroke, including discussions on the latest rehabilitation techniques that incorporate neuroplasticity principles, further endorsing the integration of innovative robotic therapies in early stroke recovery protocols.

In conclusion, the cumulative evidence suggests that robot-assisted therapies represent a valuable complement to traditional stroke rehabilitation methods. By capitalizing on the brain's neuroplasticity, these interventions promise to advance the functional recovery in patients suffering from upper limb impairments post-stroke. However, further research is required to establish standardized protocols that maximize the benefits of these technological advancements.

## METHODOLOGY

The study was conducted as a randomized controlled trial (RCT) at a rehabilitation facility in Qatar. It was designed to assess the efficacy of the Advanced Stroke Upper Extremity Program (ASUP) compared to standard therapy in improving upper limb function in stroke inpatients.

### Participants

A total of 30 inpatients who had suffered a stroke were recruited for the study. The inclusion criteria were: adults aged 18-80 years who had experienced a stroke within the last three to six months and demonstrated upper limb motor deficits. Exclusion criteria included patients with additional neurological disorders, severe cognitive impairment, or those who had undergone upper limb orthopedic surgery.

### Randomization and Interventions

Participants were randomly assigned to two groups using a computer-generated randomization schedule. Fifteen patients were allocated to the control group, which received standard therapy, and fifteen to the experimental group, which received standard therapy plus the ASUP. Standard therapy included conventional physiotherapy and occupational therapy, consisting of muscle strengthening, range of motion exercises, and functional training. The ASUP consisted of robot-assisted therapy tailored to the patient's specific deficits, focusing on repetitive task-specific training to promote neuroplasticity.

### Outcome Measures

The primary outcome measure was the Action Research Arm Test (ARAT), a performance-based test to assess upper limb motor function, including grasp, grip, pinch, and gross movement. ARAT was administered to both groups by trained evaluators who were blinded to group allocation, at two time points: pre-intervention and post-intervention, which was after a treatment period of six weeks.

**Statistical Analysis**
Intragroup and intergroup differences in ARAT scores were analyzed. A paired t-test was used to assess the within-group changes from pre- to post-intervention. An independent t-test was used to compare the changes between the control and experimental groups. The level of significance was set at $p<0.05$. All analyses were conducted using statistical software.

**Ethics**
The study was approved by the Institutional Review Board of the rehabilitation facility. Informed consent was obtained from all participants prior to inclusion in the study.

## RESULTS
The randomized control trial aimed at assessing the efficacy of the Advanced Stroke Upper Extremity Program (ASUP) during inpatient stroke rehabilitation yielded quantifiable data on upper extremity function improvements. The results, encapsulated within pre- and post-intervention assessments, utilized the Action Research Arm Test (ARAT) as the evaluative tool, scoring patients across a range from 0 (no arm function) to 57 (full arm function).

**Pre-Intervention Upper Extremity Function**
Initial assessment of upper limb function presented a baseline for both control and experimental groups. The control group demonstrated a mean pretest ARAT score of 3.85 with a standard deviation (SD) of 9.52, suggesting significant upper extremity impairment. Similarly, the experimental group had a mean pretest score of 4.14 (SD = 9.48), indicating comparable initial conditions for both groups.

**Post-Intervention Upper Extremity Function**
Upon completion of the intervention, the control group exhibited a post-test mean ARAT score of 23.21 (SD = 5.31), reflecting a moderate ability range and suggesting improvement in upper limb function. The experimental group, which underwent ASUP, recorded a mean post-test ARAT score of 31.43 (SD = 17.51), also indicating enhancement in motor abilities.

| Group | Pretest ARAT Scores (Mean ± SD) | Post-test ARAT Scores (Mean ± SD) | Mean Improvement |
|---|---|---|---|
| Control | 3.85 ± 9.52 | 23.21 ± 5.31 | 19.36 |
| Experimental | 4.14 ± 9.48 | 31.43 ± 17.51 | 27.29 |

**Table 1: ARAT Scores Before and After Intervention**

| Statistical Metric | Control Group | Experimental Group |
|---|---|---|
| Mean Improvement | 19.36 | 27.29 |
| Variance | 231.81 | 313.07 |
| Observations | 15 | 15 |
| Pooled Variance | 272.44 | - |
| t Statistic | -1.062 | - |
| P(T<=t) one-tail | 0.15 | - |
| t Critical one-tail | 1.70 | - |
| P(T<=t) two-tail | 0.29 | - |

| Statistical Metric | Control Group | Experimental Group |
|---|---|---|
| t Critical two-tail | 2.04 | - |

**Table 2: Statistical Analysis of ARAT Score Improvements**

**Statistical Analysis of Improvement**

Statistical analysis using a paired t-test examined within-group improvements, while an independent t-test compared between-group efficacy. Both groups displayed significant improvements post-intervention ($p<0.05$), confirming the effectiveness of rehabilitation in enhancing upper limb function. However, the comparative analysis between the control and experimental groups did not reveal a statistically significant difference in improvement ($t(28) = -1.062$, $p = 0.148$ for a two-tailed test). This suggests that while ASUP appeared to foster recovery, its superiority over standard therapy could not be established with statistical significance within the confines of this study's sample size and methods.

**Inter-group Variability**

Variability in outcomes was observed within both groups, as evidenced by changes in SDs from pre- to post-test scores. This reflects a range of individual responses to the interventions, which is typical in stroke rehabilitation due to the heterogeneous nature of stroke-related impairments.

**Synthesis of ARAT Score Improvements**

The majority of the control group transitioned from low to moderate ability, while the experimental group showed a shift towards the higher end of moderate ability and, in some cases, high ability. Participant 9 in the control group achieved a perfect score (57), demonstrating full recovery in upper limb function, and participant 11 in the experimental group mirrored this outcome.

## CONCLUSION

The data corroborates that both standard rehabilitation and ASUP are beneficial for improving upper extremity function post-stroke. Nonetheless, the added benefit of ASUP, as measured by ARAT scores, did not significantly exceed the outcomes of the standard rehabilitation practices provided during inpatient care.

## DISCUSSION

The randomized control study aimed to evaluate the effectiveness of the Advanced Stroke Upper Extremity Program (ASUP) during inpatient stroke rehabilitation. While both the control and experimental groups showed significant improvements in upper extremity function as measured by the ARAT scores, the anticipated superiority of ASUP over standard therapy was not statistically confirmed.

**Interpretation of Results**

The observed improvements in ARAT scores post-intervention align with the growing body of evidence supporting the efficacy of targeted rehabilitation programs in enhancing motor function post-stroke. The control group's improvement underscores the fundamental value of standard rehabilitation practices, while the experimental group's gains highlight the potential of ASUP in fostering neuroplasticity and motor recovery (Meyer et al., 2021).

However, the lack of a statistically significant difference between the groups raises questions about the added value of ASUP over conventional therapies. This finding echoes the nuanced landscape of stroke rehabilitation, where the variability in patient response is influenced by factors like stroke severity, individual patient characteristics, and the timing of intervention (Rodgers et al., 2019).

### Comparative Analysis with Existing Literature

The study's outcomes resonate with the broader discourse in stroke rehabilitation, where the integration of robotic technologies and structured therapy programs has shown promise but not unequivocal superiority over traditional methods (Bertani et al., 2017; Singh et al., 2021). The modest advantage of robotic and advanced therapies observed in some studies may be attributed to the enhanced intensity and specificity of these interventions, which are known to be critical factors in driving neuroplastic changes and functional improvements post-stroke (Clark et al., 2019).

### Limitations

The study's sample size and the inherent variability in stroke recovery trajectories may have contributed to the inconclusive findings regarding ASUP's superiority. Future research with larger sample sizes, more diverse patient populations, and longer follow-up periods could provide deeper insights into the specific contexts in which ASUP and similar programs excel.

### Implications for Clinical Practice

Despite the absence of clear superiority in this study, the improvements noted in both groups reinforce the importance of structured, intensive rehabilitation programs in stroke recovery. Clinicians should continue to leverage a combination of traditional and innovative therapies, tailored to the individual needs and progress of each patient, to optimize recovery outcomes.

### Future Directions

Investigating the differential impacts of various rehabilitation modalities on specific facets of motor function, the role of patient engagement, and the integration of cognitive and psychosocial support into rehabilitation programs could further elucidate the multifaceted nature of stroke recovery. Additionally, exploring the cost-effectiveness and practicality of implementing programs like ASUP in diverse healthcare settings would be valuable.

## CONCLUSIONS

The randomized control study set out to assess the efficacy of the Advanced Stroke Upper Extremity Program (ASUP) within the context of inpatient stroke rehabilitation. By comparing the outcomes in upper extremity function between the control group, which received standard rehabilitation care, and the experimental group, which engaged in the ASUP, this investigation aimed to provide insight into the added value of ASUP in stroke recovery. The findings indicated improvements in upper extremity motor function for both groups post-intervention, as measured by the Action Research Arm Test (ARAT). However, the anticipated statistical superiority of the ASUP over conventional therapy was not confirmed within the study's parameters. Both groups demonstrated significant gains, yet the difference in improvements between the control and experimental groups did not reach

statistical significance. These results underscore the complexity of stroke rehabilitation, where multiple factors, including the nature and severity of the stroke, the timing of the intervention, and individual patient characteristics, play a crucial role in recovery outcomes. The findings align with existing literature, suggesting that while advanced rehabilitation programs like ASUP hold promise, their superiority over traditional methods is not universally established and may depend on specific contextual factors (Meyer et al., 2021; Rodgers et al., 2019). The study's implications for clinical practice are twofold. First, it reinforces the importance of intensive and structured rehabilitation programs in enhancing post-stroke recovery. Second, it highlights the need for personalized rehabilitation strategies that consider the unique needs and recovery trajectories of each patient.

Future research should aim to address the limitations observed in this study, particularly concerning sample size and diversity. Further investigations could also explore the long-term effects of ASUP, the impact on different stroke severities, and the cost-effectiveness of implementing such programs in various healthcare settings.

In conclusion, while the ASUP demonstrated potential in improving upper extremity function in stroke patients, its benefits over standard care were not conclusively proven in this study. The findings contribute valuable insights to the field of stroke rehabilitation, emphasizing the need for ongoing research and innovation in therapeutic approaches to maximize patient recovery and quality of life.

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