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ORIGINAL ARTICLE

INFLUENCE OF ROBOTIC HAND GLOVES ON HAND FUNCTION IN STROKE SURVIVORS

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ABSTRACT

Introduction: Stroke is one of the leading causes of long-term disability worldwide and frequently results in impaired upper limb and hand functions. Recent advances in rehabilitation technology have introduced wearable robotic devices to enhance repetitive, task-oriented training and promote neuroplasticity. The present study aimed to evaluate the effectiveness of robotic hand glove therapy integrated with task-oriented training on hand motor function among stroke survivors.

Method: A quasi-experimental design with forty-two individuals with subacute stroke survivors were recruited from Thulir physiotherapy & rehabilitation center. Erode. Participants were allocated into two groups: a robotic hand glove group (RHG) receiving task-oriented training combined with robotic-glove exercises (TOT), and another group receiving task-specific exercises along with robotic glove. The intervention was conducted for eight weeks under supervised conditions. Outcome measures included the Action Research Arm Test (ARAT), Nine-Hole Peg Test (NHPT), and Stroke Impact Scale (SIS), assessed at baseline, mid-intervention, and post-intervention to evaluate changes in dexterity, functional performance, and perceived recovery.

Result: Statistical analysis with repeated measures ANOVA showed significant time effects across outcomes ($p < 0.001$), and Bonferroni analysis confirmed progressive differences between all intervals. In the RHG mean ARAT improved from 16.33 to 23.52 and 34.38, whereas TOT improved from 16.38 to 20.33 and 25.57. NHPT time decreased in RHG from 85.86 to 65.48 and 49.67, while TOT reduced from 85.10 to 72.91 and 63.24. SIS scores increased in RHG from 29.14 to 51.48 and 61.43, compared to TOT improvement from 29.33 to 38.24 and 47.29.

Conclusion: This study concluded as robotic-gloves along with task-oriented rehabilitation offers excellent hand recovery in stroke survivors.

Keywords: Hand Function, Neurorehabilitation, Robotic Hand Glove, Stroke survivors, Task-Oriented Training.

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INTRODUCTION

Stroke remains a major global health concern and is one of the leading causes of mortality and long-term disability, particularly in developing countries.[1] In recent years, the burden of stroke has increased markedly in India, where both incidence and prevalence continue to rise.[1] Current epidemiological reports indicate that stroke is the fourth leading cause of death and the fifth leading cause of disability in India.[2]

Alarmingly, developing countries have also reported a steep increase, approximately 36.7%, in stroke-related deaths among younger adults, highlighting an emerging public health challenge.[3] This trend not only affects individuals during their most productive years but also places substantial emotional, social, and economic strain on families and healthcare systems.[2]

Stroke survivors commonly experience a combination of motor, sensory, and cognitive impairments that significantly affect independence and quality of life.[4] It is estimated that nearly 9 out of 10 stroke survivors live with some form of long-term disability, although the type and severity vary across individuals. These persistent impairments often require prolonged rehabilitation and support, contributing to considerable human and economic costs.[5]

Consequently, stroke rehabilitation has evolved into a comprehensive and multidisciplinary process involving physiotherapists, occupational therapists, nurses, social workers, and physiatrists working collaboratively to restore function and minimize long-term complications.[6] The primary goal of rehabilitation is to help individuals regain confidence, perform daily activities independently, return to social and occupational roles, and improve overall participation in life situations.[7]

Among the various impairments following stroke, upper limb dysfunction, particularly hand impairments, remain one of the most common and challenging deficits.[4] A large proportion of stroke survivors experience reduced hand function, which limits their ability to perform essential daily tasks such as grasping, holding, and manipulating objects.[8] Recovery of hand function is often slow and incomplete because stroke-related neural damage disrupts motor pathways and leads to hemiparesis, poor coordination, and reduced dexterity.[9] The biomechanical complexity of the hand, combined with the intricate neural control required for fine motor activity, makes rehabilitation of hand function particularly difficult.[8]

Traditional rehabilitation approaches, including strengthening and range-of-motion exercises, are helpful but may not always provide sufficient intensity or task-specific practice to optimize neuroplastic recovery. The restoration of hand function after neural injury remains challenging, and available intervention strategies are still limited.[9] In recent years, technological advances have introduced robotic-assisted rehabilitation as a promising approach to enhance motor recovery. Wearable soft robotic hand gloves have emerged as innovative devices designed using flexible materials that assist finger movement by transmitting controlled forces to both the dorsal and palmar surfaces of the hand. [(8)] These devices facilitate repetitive opening and closing movements through assisted contraction and relaxation of hand muscles and tendons, thereby promoting motor relearning.[10]

Although several rehabilitation methods target upper and lower limb deficits after stroke, research focusing specifically on individuals with significant hand impairment remains limited. Furthermore, only a small number of studies have examined how improvements in hand motor function translate into meaningful performance in everyday activities. This gap highlights the need for rehabilitation approaches that combine technological assistance with functional, task-specific practice.

Therefore, the present study hypothesizes that integrating robotic hand glove therapy with task-oriented training will produce greater improvements in hand function. The primary purpose of this study is to evaluate the effectiveness of robotic hand gloves combined with task-specific training in enhancing hand motor function and functional performance among stroke survivors.

METHODOLOGY

This quasi-experimental study was conducted over a period of two years and included forty-two stroke survivors recruited from Thulir Physiotherapy & Rehabilitation Centre. Ethical approval for the study was obtained from the Institutional Ethics Committee of the Department of Physiotherapy at Madhav University. All participants were informed about the study procedures, and written consent was obtained prior to their inclusion.

Participants aged between 45 and 64 years were screened for eligibility. Both male and female stroke survivors were included if they had experienced either ischemic or hemorrhagic stroke involving the middle cerebral artery (MCA). Additional inclusion criteria were upper limb motor power less than or equal to grade 3, the ability to walk with support, adequate comprehension to follow instructions, the ability to sit independently, and the ability to initiate arm lifting. Individuals were excluded if they were presented with significant cognitive impairment, instability of wrist or finger joints, severe hand contractures, hand pain, or psychological instability that could interfere with participation.

Eligible participants were assigned into two groups using a non-random allocation procedure based on predefined recruitment criteria. Group allocation was performed by the treating department to maintain balanced group distribution. Assessor conducted outcome evaluations at baseline (week 1), mid-intervention (week 3), and post-intervention (week 8). The sample size was estimated based on findings reported by Thimabut et al. (2022)[11] using a power and sample size calculator. Previous literature indicated a 21–26% improvement in ARAT scores following robotic hand therapy with a significance level of $p < 0.001$. Using an effect size of $f = 0.25$ for a repeated-measures design with three assessment points, 80% statistical power, and a 5% significance level, the required sample size was calculated as 36 participants. To account for an anticipated dropout rate of approximately 15%, the final sample size was increased to 42 participants.

Participants in the first group, referred to as the Robotic Hand Glove Group (RHG), underwent task-oriented training focusing on functional movements of the elbow, wrist, and hand for 30 minutes, followed by 10 minutes of robotic hand glove therapy. The second group, referred to as the Task-Oriented Group (TOG), received the same 30-minute task-oriented training program followed by 10 minutes of robotic gloves was given. All sessions were supervised by trained therapists who ensured proper execution of exercises and aided when necessary. Both groups were also given structured home exercise programs emphasizing hand function to encourage continued practice outside the clinical setting. Both groups underwent supervised treatment sessions on alternate days, totaling three sessions per week, and the intervention was continued for eight weeks.

Participants in the task-oriented training started with a slow, sustained passive range of motion exercises for the fingers, wrist, elbow, and shoulder, performed for 10 repetitions each. This was followed by progressive strengthening exercises for 10 minutes using resistance based on one-repetition maximum (1RM).[8] Functional, task-specific activities were then carried out for an additional 10 minutes to simulate activities of daily living. These included picking pebbles, grasping a spoon, pouring water into a glass, turning a doorknob, buttoning a shirt, zipping, and tying shoelaces, as described by Bayindir (2022).[12] These structured activities were selected to enhance coordinated upper-limb movement and to improve functional hand performance in everyday tasks.

Robotic-assisted therapy was delivered using the portable rehabilitation robot glove developed by SHOPVILLA. The device is designed specifically for stroke and hand rehabilitation, with a lightweight and portable structure that enhances patient comfort and usability.[13] It operates through a pneumatic (air-pressure) driven mechanism that assists finger flexion and extension, enabling repetitive, task-oriented movement practice and supporting motor recovery.[13]

Outcome measures included the Action Research Arm Test (ARAT), Nine-Hole Peg Test (NHPT), and Stroke Impact Scale (SIS), which were administered at each assessment point to evaluate hand function, dexterity, and functional recovery.[11] Continuous variables were summarized using mean and median values, while categorical variables were presented using frequency and percentage distributions. Repeated measures ANOVA was used to compare outcome measures across assessment periods within and between groups, followed by Bonferroni post hoc analysis for pairwise comparisons where appropriate. All statistical analyses were performed using SPSS Statistics for Windows, version 25.0 (IBM), with statistical significance set at $p < 0.05$.

Out of the total 42 participants initially recruited for the study, four participants did not complete the intervention period. Specifically, two participants from the Robotic Hand Glove Group (RHG) and two participants from the Task-Oriented Training Group (TOT) withdrew due to personal reasons, family-related issues, and transfer to other locations during the study period. Consequently, the final analysis was conducted on 38 participants who completed the full intervention protocol and assessment schedule.

RESULT

This table 1 shows the repeated measures ANOVA demonstrated statistically significant improvements across all assessment periods in ARAT, NHPT, and SIS scores in both groups ($p < 0.001$). However, the Robotic Hand Glove Group showed greater improvement compared to the Task-Oriented Group, indicating superior effectiveness of robotic-assisted task-oriented training in enhancing hand motor function, dexterity, and functional independence in individuals with subacute stroke.

Table 2 shows Bonferroni post hoc analysis demonstrated statistically significant differences between all-time intervals (Pre, Post I, and Post II) for ARAT, NHPT, and SIS in both groups ($p < 0.001$). Greater mean changes were observed in the Robotic Hand Glove Group compared to the Task-Oriented Group, indicating superior improvement in hand function and stroke-specific quality of life across the intervention period**.**

Both groups showed consistent improvement across all outcome measures (ARAT, NHPT, and SIS) from baseline to Post I and Post II, with greater gains observed in the Robotic Hand Glove group (RHG) compared to the Task-Oriented training group (TOT). Mean scores indicated marked functional progression over time, particularly in RHG, reflecting better recovery in hand dexterity, motor performance, and stroke-related functional outcomes.

Repeated measures ANOVA demonstrated a significant effect of time for all three outcomes in both groups ($p < 0.001$), confirming that the interventions produced meaningful clinical changes. The RHG showed higher F-values across ARAT, NHPT, and SIS, indicating stronger treatment effects compared to TOT. Post hoc analysis further revealed significant differences between all assessment intervals (Pre vs Post I, Pre vs Post II, and Post I vs Post II), supporting progressive improvement throughout the intervention period. Overall, the results suggest that adding robotic-assisted training to task-oriented practice enhances upper limb recovery more effectively than task-oriented training alone.

Table 1
Anova Analysis of the Outcome Measures

Outcome	Group	Pre	Post I	Post II	F value	p value
ARAT*	**RHG**	**16.33 ± 0.97**	**23.52 ± 2.64**	**34.38 ± 1.49**	**723.80**	**<0.001**
	TOT	**16.38 ± 0.94**	**20.33 ± 1.84**	**25.57 ± 1.28**	**261.03**	**<0.001**
NHPT*	**RHG**	**85.86 ± 2.40**	**65.48 ± 2.52**	**49.67 ± 2.86**	**1006.95**	**<0.001**
	TOT	**85.10 ± 2.25**	**72.91 ± 1.92**	**63.24 ± 2.42**	**710.31**	**<0.001**
SIS*	**RHG**	**29.14 ± 1.75**	**51.48 ± 1.56**	**61.43 ± 1.29**	**2783.21**	**<0.001**
	TOT	**29.33 ± 2.01**	**38.24 ± 1.63**	**47.29 ± 2.05**	**506.14**	**<0.001**

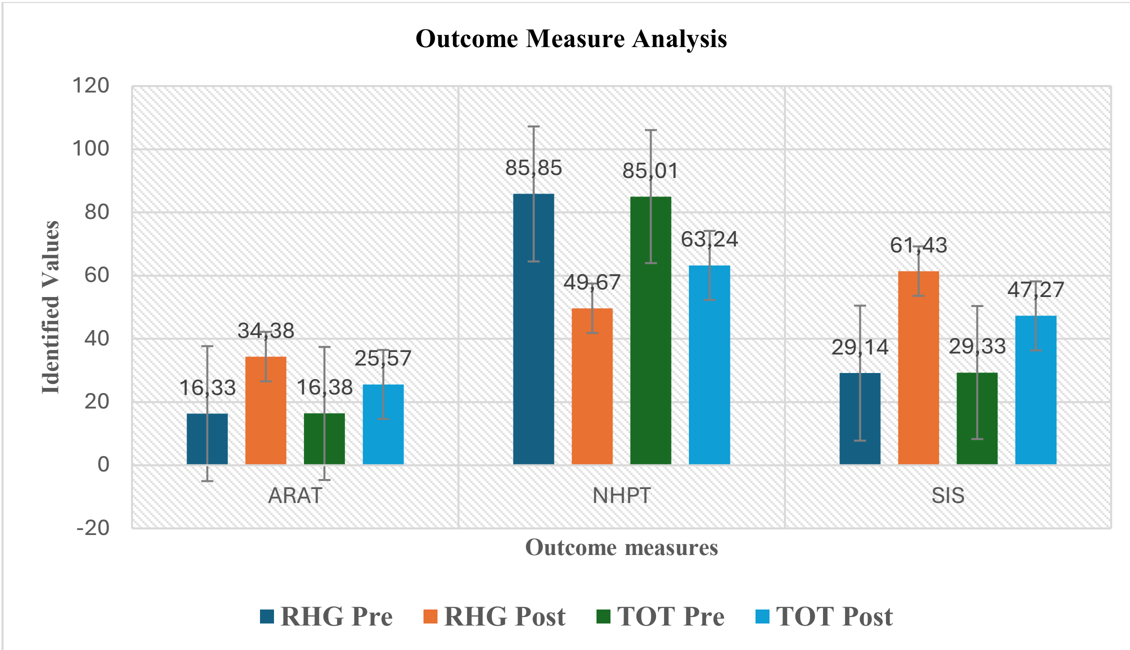
***ARAT :** Action Research Arm Test, **NHPT** : Nine-Hole Peg Test, **SIS** : Stroke Impact Scale. **RHG** : Robotic Hand Gloves, **TOT**: Task oriented training group

Table 2

Post-Hoc Analysis

Outcome	Group	Pre vs Post I (Mean Diff)	Pre vs Post II (Mean Diff)	Post I vs Post II (Mean Diff)	p value
ARAT	**RHG**	7.19	18.05	10.86	<0.001
	TOT	3.95	9.19	5.24	<0.001
NHPT	**RHG**	20.38	36.19	15.81	<0.001
	TOT	12.19	21.86	9.67	<0.001
SIS	**RHG**	22.33	32.29	9.952	<0.001
	TOT	8.91	17.95	9.05	<0.001

Graph I



DISCUSSION

The present study aimed to evaluate the effectiveness of robotic hand gloves integrated with task-oriented training in improving hand motor function among stroke survivors. The findings showed significant improvement across all outcome measures in both groups; however, the gains were more pronounced in the robotic glove group. In addition to improvements in motor performance, participants who received robotic-assisted training also demonstrated better functional use of hand in activity-based tasks. These results suggest that combining robotic assistance with task-specific practice may enhance the overall rehabilitation effect.

One possible explanation for these findings is the increased intensity and repetition provided by robotic-assisted training. Repetitive practice of meaningful movements is known to facilitate motor recovery after stroke. Earlier work by multiple researchers emphasized that structured and repeated upper limb activity can significantly improve functional outcomes in stroke rehabilitation.[11,12] Similarly, Karishma et al., 2024 reported that repetitive passive and assisted finger movements can modify the inhibitory mechanisms of the central nervous system and enhance activity-dependent neuroplasticity, thereby supporting improved motor responses.[13]

In the current study, participants in the robotic glove group showed consistent improvement across all assessment periods, indicating progressive motor recovery. These findings align with previous studies supporting robotic-glove rehabilitation. Previous literature suggests that the combined application of functional electrical stimulation and robotic hand glove therapy is more effective in improving task-specific upper limb activities in post-stroke individuals.[14] These improvements are particularly evident in functional movements such as reaching, grasping, releasing, lifting objects, and drinking tasks.

Robotic gloves are typically designed with lightweight woven materials integrated with pneumatic actuators that assist finger movements while maintaining comfort and adaptability to the user's hand. Additionally, the use of flexible and low-cost materials in these devices highlights their potential as an affordable and practical solution for hand rehabilitation in stroke recovery.[15] Together, these findings reinforce the growing evidence that robotic-assisted interventions can enhance functional recovery after stroke. The effectiveness of robotic glove training may also be attributed to its ability to deliver intensive, repetitive, and task-oriented movement practice. Calabro (2019) suggested that such structured and high-frequency training promotes motor learning and reduces motor deficits through cortical reorganization.[10] Robotic-assisted movements are thought to stimulate neurophysiological changes by improving movement-related brain oscillations and strengthening functional connectivity. Studies by Thimabut (2022) and Karishma (2024) further reported that robotic hand training contributes to improved sensorimotor integration and corticospinal excitability, supporting interhemispheric balance and enhancing neural plasticity.[11,13]

Task-oriented training itself plays a critical role in stroke recovery. According to Anne Shumway-Cook (2012), task-specific practice is grounded in principles of motor control and motor learning, where active participation and skill acquisition drive functional improvement.[16] Experimental evidence demonstrated that task-specific training can promote cortical reorganization by recruiting adjacent or alternative neural pathways.[17] Additionally, Kwakkel (2015) highlighted that task-oriented interventions enable patients to optimize the use of remaining motor control, particularly in individuals with residual voluntary wrist and finger movements. [(18)]

From a clinical perspective, the improvements observed across ARAT, NHPT, and SIS indicate that robotic glove-assisted training may provide meaningful functional benefits in stroke rehabilitation. The robotic glove used in this study demonstrated good feasibility due to its lightweight design, ease of handling by therapists, and simple operation that enabled better patient understanding and participation during training sessions. In addition, the universal-fit design allowed its use across different hand sizes without the need for extensive modification. The relatively low-cost nature of the device may further support its practical implementation and accessibility in rehabilitation settings. No intervention-related adverse events were observed during the study period, supporting the safety of the intervention.

The findings of the present study indicate that integrating robotic gloves with task-oriented training leads to meaningful improvements in both hand function and activities of daily living. However, research specifically focusing on wearable robotic gloves for stroke rehabilitation remains limited, and further investigation is needed to strengthen the evidence base. Based on the outcomes observed in this study, the use of robotic-assisted task-oriented training can be recommended as an effective approach to enhance functional hand recovery after stroke.

Some limitations of this study noted are this study took a small sample size (n = 42) and was conducted at a single center, which may limit generalizability. Participants' daily activities outside therapy were not controlled, and no long-term follow-up was performed to assess the sustainability of improvements. Blinding of participants and therapists was not possible, introducing potential performance and Hawthorne effects. Additionally, ADL outcomes were primarily assessed using the Stroke Impact Scale, without incorporating other hand-specific functional measures such as the ABILHAND Questionnaire or the Motor Activity Log.

CONCLUSION

In conclusion, this study demonstrates that combining robotic hand glove training with task-oriented practice results in significantly greater improvements in hand and upper limb functional performance in individuals with subacute stroke.

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AUTHOR CONTRIBUTION:

Dr. Anandan: Conceptualization of the study, study design, supervision, and critical revision of the manuscript. Dr. Ashok: Data collection, statistical analysis, and interpretation of results. Dr. Arun: Physiotherapy assessment, intervention planning, and drafting of the rehabilitation methodology sections. Dr. Sathish Kumar: Literature review, manuscript drafting, editing, and final manuscript preparation. All authors reviewed and approved the final version of the manuscript.

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CONFLICT OF INTEREST:
The authors declare no conflicts of interest.

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