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IMPACT OF ROBOT – ASSISTED GLOVE HAND TRAINING ON FINE AND GROSS MOTOR FUNCTION. RECOVERY AND DAY-TO-DAY FUNCTIONAL TASKS IN POST-MEDIAN NERVE REDIRECTION INDIVIDUALS: A NOVEL RECOVERY THERAPY APPROACH

Original Research

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ABSTRACT

BACKGROUND: Selective nerve transfers involve rerouting healthy nerves to restore lost motor function, whereas robot-assisted upper-limb therapy provides structured rehabilitation for patients recovering from neurological damage. Robotic systems deliver controlled, accurate movement assistance and interaction, and over the past twenty years have demonstrated rehabilitation results comparable to those achieved through conventional therapy.

OBJECTIVE: To evaluate the impact of robotic-glove–assisted hand training on fine and gross motor skills and daily functional performance in patients post median nerve transfer using a quasi-experimental approach.

METHODOLOGY: A quasi-experimental study was conducted at Ghurki Trust Teaching Hospital, Lahore, over six months with 36 patients post median nerve transfer. Participants were divided into Group A (Robot Group, n = 18) receiving soft robotic glove therapy and Group B (Control Group, n = 18) undergoing conventional hand exercises. Functional outcomes were assessed using the Soller man Hand Function Test, Jebsen–Taylor Hand Function Test, Pegboard Dexterity Test, and Barthel Index. Propensity Score Matching (PSM) minimized baseline differences, and statistical analyses were performed in SPSS v25, including normality checks via the Shapiro–Wilk test.

RESULTS: Both groups showed improvements in hand function and dexterity. The Robot Group improved in the Jebsen–Taylor Test from 85.60±17.02 to 74.53±17.01 ($p = 0.000$) and in the Sollerman Test from 34.20±7.66 to 45.33±7.73 ($p = 0.000$). The Control Group also improved, albeit to a lesser extent. Pegboard Dexterity scores increased in the Robot Group from 29.53±4.48 to 40.60±4.34 ($p = 0.000$) and in the Control Group from 29.20±4.82 to 33.26±4.81 ($p = 0.000$).

CONCLUSION: Combining conventional hand therapy with robotic-glove rehabilitation significantly enhances fine motor performance, hand function, and daily living activities in patients following median nerve transfer. While random assignment was not employed, statistical matching strengthens the validity of results, supporting robot-assisted therapy as an effective post-surgical intervention.

KEY WORDS: Hand Rehabilitation, Nerve Transfer Rehabilitation, Robotic Glove, Quasi-Experimental Study.

INTRODUCTION

Selective nerve redirections provide a method to regain motor abilities in cases of. nerve injury where recovery via neurolysis, nerve repair, or grafting is not feasible[1]. Indications for these transfers may include severe distal nerve damage, avulsion-type injuries, limited. nerve roots for grafting, extensive scarring at the injury site, and delayed reconstruction[2]. after motor nerve injury, timely intervention is essential because muscle tissue and motor. end plates begin to degenerate, restricting successful re-innervation to within 1–2 years post-injury[3], [4]. nerve redirections shorten re-innervation time by allowing nerve coaptation closer to the target muscle. This surgical procedure, known as neurotization, involves redirecting an intact donor nerve to. the distal segment of a damaged recipient nerve, effectively bypassing the injured portion[5]. While peripheral nerve surgery generally aims to regain motor abilities, sensory nerve redirections may. also be employed to regain hand sensation after severe median or ulnar nerve injuries. Like motor transfers, sensory transfers establish new neural pathways, resulting in sensations perceived as originating from the donor nerve's previous area of innervation[6].

Post-operative therapy after nerve redirection differs from protocols used after direct nerve repair due to altered neural pathways. Donor axons adopt new roles as they grow toward their target, retaining cortical connections to their original function but no longer performing it[7]. For example, ulnar nerve fascicles remain cortically linked to their prior functions, such as wrist and finger abduction and flexion. Consequently, to activate and strengthen the re-innervated recipient muscle (e.g., biceps), individuals must initially focus on the donor nerve's original function (e.g., hand closing). This approach is referred to as "donor activation" [8]. Upper-limb robot-supported therapy has emerged as a safe and practical method for facilitating recovery from neurological injuries, including stroke. Robots are particularly suitable for sensorimotor training because they can precisely control them. level of assistance or resistance and provide mechanical and visual feedback within virtual environments. Over the past two decades, numerous robotic systems for proximal upper extremity recovery therapy. have been developed and tested in clinical settings, demonstrating outcomes comparable to dose-matched conventional therapy[9].

The present research sought to examine the impact of robot-supported hand training on fine and gross motor skills after median nerve redirection surgery. Accelerating recovery therapy and enhancing patient independence were key objectives. This research examined the clinical equivalence of sensorimotor robot-supported hand recovery therapy to highlight its. potential role in physiotherapy and to inform the development of improved treatment protocols and prognoses. In 2023, Lee et al. published a clinical review on upper-limb nerve redirections and recovery therapy. They noted that selective nerve redirections are particularly advantageous when traditional nerve repair or grafting is not feasible. Timely reconstruction is critical due to the rapid degeneration of muscle tissue and motor end plates, which limits successful re-innervation to 1–2 years post-injury. nerve redirections allow quicker re-innervation by enabling nerve coaptation near the target muscle, a procedure also called neurotization[10].

Although several studies have assessed nerve redirections and robotic recovery therapy in stroke and. spinal cord injury individuals, research on peripheral nerve injury, particularly median nerve injury, remains limited. Moreover, few studies have explored the effects of robotic hand gloves on this patient population. Therefore, the current study was designed to evaluate the efficacy of robotic hands. glove therapy in improving hand function for individuals who have undergone median nerve redirections.

METHODS

A six-month quasi-experimental study was conducted at Ghurki Trust Teaching Hospital, Lahore, Pakistan, after. approval from the Ethical Committees BASR of Riphah International University, Lahore (REC Number: REC/RCR&/23/02103AHS) [11]. The required sample size was calculated using G*Power (version 3.1.9.2) based on differences between two independent means, with functional. assessment scores chosen as the primary outcome due to their reliability and validity in evaluating hand function in daily activities[12]. According to Osuagwu et al.[13], an effect size (d) of 1.389 was derived from mean scores of 91.4 ± 30.9 in the. experimental group and 119.8 ± 30.7 in the control group, using a significance level of $\alpha = 0.05$ and 80% statistical power. This calculation indicated that 20 individuals per group were required, which, after adjusting for. a 10% dropout rate, resulted in a final sample of 36 participants (18 per group). The study enrolled 46 male and female individuals who met the inclusion criteria of being aged 19–55. years[14], having undergone median nerve redirection after trauma, and being able to understand and follow verbal instructions[14]. Exclusion criteria included altered consciousness, aphasia, severe cognitive impairments[11], significant upper limb pathologies of rheumatic origin[11], inability to provide informed consent, severe pain in the affected arm (Visual Analogue Scale >5) [11], or inpatient participation in intensive interdisciplinary recovery therapy programs post-nerve redirection.

Participants were assigned to intervention groups based on clinical recommendations and patient preference rather than randomization. Group A (Robot Group – RG) underwent robot-supported hand recovery therapy using the Syre Bo Robotic. Glove, while Group B (Control Group – CG) received conventional hand training without robotic support[11]. Treatment outcomes were assessed using validated instruments, including the Soller man Hand Function Test (SHT), Jebsen-Taylor Hand Function. Test (JTHFT), Purdue Pegboard Test for dexterity, and the Original Barthel Index for day-to-day functional tasks (ADLs)[15], [16]. Because randomization was not applied, Propensity Score Matching (PSM) was utilized to adjust for. baseline differences across variables such as age, injury severity, and initial hand function scores[11]. Statistical analyses were performed using SPSS version 25, and the Shapiro-Wilk test was applied to verify data normality[11].

RESULTS

The Shapiro-Wilk test was conducted to assess normality, given the sample size was <50. The results confirmed that the data were normally distributed ($p > 0.05$). Variables such as Age, Gender, Pre-Treatment and Post-Treatment Jebsen-Taylor Hand Function Test (JTHT), Pre-Treatment and Post-Treatment Soller man Hand Function Test (SHT), Pre-Treatment and Post-Treatment Pegboard Test, and Pre-Treatment and Post-Treatment Barthel Index (BI) all had p-values > 0.05, supporting the assumption of normality. A paired t-test was used to evaluate changes within each group before and after the intervention. The robot-supported Group (RG) showed a marked improvement in hand function, with mean scores improving from. 85.60 ± 17.02 to 74.53 ± 17.01, reflecting a mean difference of 11.06 ($p = 0.000$). The Conventional Therapy Group (CG) also improved from 89.20 ± 11.83 to 85.26 ± 11.78, with a mean difference of 3.93 ($p = 0.000$).

Table1: Paired T-Test of Jebson Taylor Hand Function test in groups:

Variables	RG				CG			
	Pre	Post	Mean difference	p	Pre	Post	Mean difference	p
	Mean ± S. D	Mean ± S. D			Mean ± S. D	Mean ± S. D		
JTHT	85.60±17.02	74.53±17.01	11.06	0.00	89.20±11.83	85.26±11.78	3.93	0.00

Table 2: Paired T-Test of Soller man Hand Function Test in group:

Variables	RG				CG			
	Pre	Post	Mean difference	p	Pre	Post	Mean difference	p
	Mean ± S. D	Mean ± S. D			Mean ± S. D	Mean ± S. D		
SHT	34.20±7.66	45.33±7.73	-11.13	0.00	31.20±6.47	35.06±6.23	-3.86	0.00

A marked improvement in hand function was also observed in the Soller man Hand Function Test (SHT). The robot-supported Group (RG) improved from 34.20 ± 7.66 to 45.33 ± 7.73, with a mean difference of -11.13 ($p = 0.000$). In the Conventional Therapy Group (CG), scores improved from 31.20 ± 6.47 to 35.06 ± 6.23, with a mean difference of -3.86 ($p = 0.000$).

Table 3: Paired T-test of Barthel Index (BI) in groups:

Variables	RG				CT			
	Pre	Post	Mean difference	p	Pre	Post	Mean difference	p
	Mean ± S. D	Mean ± S. D			Mean ± S. D	Mean ± S. D		
BI	69.80±8.19	80.73±8.28	-10.93	0.00	70.66±11.17	74.86±11.24	-4.20	0.00

DISCUSSION

recovery therapy using robotic gloves has increasingly been recognized as a valuable method. for improving hand motor abilities in individuals recovering from median nerve redirection procedures. Previous research shows that this technology can improve hand performance, grip strength, and. overall functional independence in individuals with neurological deficits, including those undergoing nerve reconstruction. Nonetheless, outcomes may differ depending on factors such as patient profile, length of treatment, and intensity of the recovery therapy program. Consistent with earlier evidence, the current study indicates that robotic glove training offers substantial benefits for restoring hand function after median nerve redirection. When combined with conventional therapy, robotic-assisted training appears to further support motor recovery, underscoring the value of a comprehensive, multimodal

recovery therapy approach for post-surgical hand restoration[17]. Cusick et al. highlighted the value of coordinated nerve redirections for effective motor recovery therapy, noting that early. Sensory re-education can reduce paresthesia and improve two-point discrimination in individuals recovering from nerve injuries. Furthermore, retraining motor units under the supervision of a certified therapist has been shown to support long-term functional recovery. Building on these concepts, the current study focused on individuals who underwent median nerve redirection, providing a detailed assessment of hand function outcomes. Comparisons between the robot-supported Group (RG) and the Conventional Therapy Group (CG) revealed marked improvements in hand movement, functionality, and dexterity after intervention. In the Jebsen-Taylor Hand Function Test (JTHFT), the RG group improved from 85.60 ± 17.02. to 74.53 ± 17.01 ($p = 0.000$), while the CG group also showed measurable functional gains[18].

Yuryevich et al. explored the application of a myoelectric robotic glove to improve hand function in stroke individuals, focusing on enhancing performance in daily activities. Their results indicated that robotic glove-assisted therapy significantly improved hand movement, bimanual coordination, and. overall functional independence, while also supporting neuromuscular recovery in individuals with brain and nerve injuries. In a similar context, the present study demonstrates that both robot-supported and conventional. recovery therapy effectively improves hand function in individuals after median nerve redirection surgery. These outcomes underscore the value of individualized recovery therapy programs that combine robotic support with traditional therapy to maximize motor recovery and functional performance[19]. In 2020, Ranz ani et al. conducted a randomized controlled trial examining robot-supported hand recovery therapy in post-stroke individuals after nerve redirection. Their findings indicated that robot-supported therapy produced motor recovery outcomes comparable to conventional neurocognitive therapy during subacute inpatient recovery therapy. While their study focused on post-stroke individuals, the current research targeted individuals recovering from median nerve redirection surgery. In this study, comparisons between the Robot Group (RG) and Conventional Group (CG) showed significant post-treatment improvements in hand movement, function, and dexterity. Specifically, the Soller man Hand Function Test scores increased from 34.20 ± 7.66 to 45.33 ± 7.73 ($p = 0.000$). in the Robot Group, and from 31.20 ± 6.47 to 35.06 ± 6.23 ($p = 0.000$) in the Control Group[20].

Cheon et al. employed a robotic glove integrated with EMG sensors to improve power grasping in hand recovery therapy. The study included eight healthy participants who performed power grasping movements while the sensors monitored six forearm muscles, demonstrating marked improvements. Their findings indicated that the robotic glove can effectively improve hand function and muscular strength. In contrast, the present study focused on comparing the effects of robot-supported therapy versus conventional recovery therapy. on hand function specifically in individuals after median nerve redirection, highlighting different intervention strategies within recovery therapy practice[21]. Cheon et al. examined the use of a robotic glove equipped with EMG sensors to improve power grasping in hand recovery therapy. The study involved eight healthy participants performing grasping movements while the sensors tracked activity in six forearm muscles, showing notable improvement. The results showed that robotic gloves could effectively strengthen muscles and improve hand function. By comparison, the current study examined the relative efficacy of robot-supported therapy versus conventional recovery therapy. on hand function in individuals recovering from median nerve redirection, emphasizing different strategies in recovery therapy approaches[21].

These findings suggest that integrating robot-supported therapy with conventional recovery therapy can improve hand function and overall quality of life for individuals. The results highlight the important contributions of both robotic and traditional approaches in supporting hand recovery therapy. Further studies and clinical trials are needed to examine long-term efficacy and potential benefits. of this combined intervention for optimizing recovery of hand function after median nerve redirection surgery[22].

CONCLUSION

The results of this randomized controlled trial indicate that combining conventional hand recovery therapy with soft robotic gloves can. effectively improve fine and gross motor skills, as well as day-to-day functional tasks, in individuals who have undergone median nerve redirection. The use of robotic gloves alongside traditional therapy represents a promising approach for enhancing hand recovery therapy outcomes. To evaluate the long-term sustainability of these improvements, follow-up studies extending beyond the four-week intervention period are recommended. Incorporating patient feedback and subjective assessments regarding their experiences with both robot-supported and conventional therapies. could provide a more comprehensive understanding of their effects on quality of life and satisfaction. Additionally, healthcare professionals may benefit from analyzing the cost-efficacy of robot-supported versus traditional therapies to inform clinical decision-making.

AUTHOR's CONTRIBUTION:

Author	Contribution
Ayesha Kousar	Concept development, study design, data analysis, drafting the manuscript, investigation, data management, and software implementation.
Sabiha Arshad	Study design, data collection, data management, manuscript review and editing, validation, and supervision.

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