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The Effects of Robotic Hand Gloves on Hand Range of Motion of Chronic Stroke Patients (2024-2025)

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Abstract

Chronic stroke patients experience persistent upper limb impairments that limit hand function resulting in reduced quality of life and overall independence in ADLs. Soft robotic hand gloves may improve hand Range Of Motion (ROM) by promoting motor learning and neuroplasticity. A descriptive-correlational pre-test and post-test study was used in this study. The participants were composed of 20 chronic stroke patients aged 55-65 years from Metro Manila - selected through a purposive sampling method. Patients underwent a total of 20 treatment sessions over the course of 6 weeks using soft robotic hand gloves, which provided repetitive, task-specific hand movements. Wrist and hand ROM was measured during the pre- and post-assessment period using a standard universal goniometer, following a protocol based on Brunnstrom's Clinical Kinesiology (2012). The data were analyzed using mean difference, paired-sample comparison, and effect size (Cohen's d). Although the results showed persistent limitations in some joint movements, the results still showed significant improvements in both active and passive ROM in different wrist and hand joint movements - which are critical movements for functional hand use for ADLs - after the intervention. The findings suggest that the use of robotic gloves improved wrist and hand flexibility, and joint movement among participants. The study suggests that robotic hand gloves can be a safe and effective technology-driven alternative or adjunct to conventional therapy, supporting motor learning and neuroplasticity, and functional recovery. Robotic-assisted rehabilitation has the potential to improve independence and quality of life for chronic stroke patients.

Keywords: Robotic Hand Gloves; Chronic Stroke Patients; Stroke Rehabilitation; Range of Motion; Motor Relearning; Neuroplasticity; Upper Limb Function

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Introduction

Stroke remains among the major causes of long-term disability which leaves a chronic impairment in upper limb function leading to considerably compromised independence and quality of life (González-Santos et al., 2023). In response, rehabilitation strategies have transitioned from the use of traditional methods toward more technology-supported interventions. Among these, robotic-assisted technologies, especially soft robotic hand-gloves, are emerging for their potential to increase dexterity and functional recovery in stroke patients (Lim et al., 2023). Neurorehabilitation has adopted task-specific, repetitive, and intensive training as vital for promoting neuroplasticity and enhancing outcomes (Sharma et al., 2023). These concepts have influenced the design of robotic equipment that can provide high-repetition therapy with precision and regularity. Soft robotic gloves are meant to support functional movements such as grasping and releasing that are necessary for everyday living. Conventional rehabilitation for stroke survivors that focuses on enhancing muscle strength, flexibility, and motor control, including manual stretching, Range of Motion exercises, and task-specific training has its significant effects for majority of the patients, but it can also be time-consuming and expensive as it involves the physical therapist in Robotic-assisted devices are able to provide high-frequency, repetitive exercises important for neuroplasticity - the brain's ability to reorganize and create new neural pathways after injury. These robotic gloves have the ability to give both passive and active support to allow patients to go through controlled motion and receive measurable feedback on improvement. Several studies have proven the ability of robotic devices in restoring motor functions. From these findings, it is implied that robotic hand gloves could offer therapeutic benefits for post-stroke patients, but have yet to be established as a better choice for functional recovery of wrist and hand range of motions than conventional therapy.

Methods

A quasi-experimental pre-test-post-test single-group design was employed to evaluate the effect of robotic hand-glove therapy on the Range Of Motion (ROM) of the hand and wrist of chronic stroke patients in the study. Purposive sampling was employed to recruit participants from Metro Manila who met the following inclusion criteria: 55-65 years of age, duration of at least six months poststroke, and at Brunnstrom Stage 4 of recovery, as well as application of certain exclusion criteria in the interest of safety and homogeneity. Baseline and post-intervention active and passive ROM were measured with a standard universal goniometer according to standardized protocols, and the same licensed PT performed all evaluations for each participant. Twenty therapy sessions in six weeks were delivered to participants with a robotic hand-glove the design of which promoted repetitive, task relevant movements. Descriptive statistics, paired samples t-tests and Cohen's d were calculated to analyze the data and to identify significant differences and the size of improvement after the intervention.

Results and Discussion

This chapter includes the data gathered from the pre-test and post-test assessments of three chronic stroke patients. The results were analyzed and interpreted to determine the effectiveness of robotic hand-gloves in improving the Hand Range of Motion (ROM).

Figure 1 shows that 60% of the participants were male, while 40% were female. This distribution indicates that males tend to have a higher incidence of stroke at earlier ages compared to females. The presence of both male and female participants strengthens the applicability of the findings. Although sex differences were not analyzed as a separate variable, the relatively balanced representation reduces the likelihood that sex alone influenced the observed improvements in hand and wrist range of motion. Instead, the improvements can be more confidently attributed to the robotic hand-glove therapy. The figure supports the generalizability of the results to both male and female chronic stroke patients who experience similar motor impairments and rehabilitation challenges.

Figure 2 presents that 55% of the participants belonged to the 60-65 age group, while 45% were within the 55–59 age range. Stroke incidence and long-term motor impairments increase with advancing age, making this population appropriate for evaluating interventions aimed at improving hand and wrist range of motion. The near-equal distribution between the two age groups also suggests that the sample was not heavily skewed toward a single age bracket, allowing for a balanced representation of late-middle-aged and older stroke survivors. The relatively narrow age range strengthens the internal validity of the study. By limiting participants to ages 55-65, age-related variability in joint stiffness, muscle elasticity, and degenerative changes was minimized.

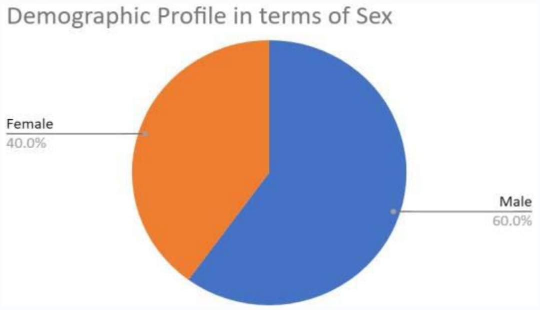

Figure 1: Sex distribution of respondents.

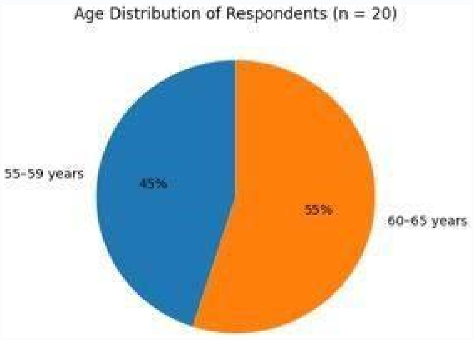

Figure 2: Age distribution of respondents.

1. Pre-Intervention Range of Motion (ROM) of Participant

Table 1 presents the pre-test Active Range of Motion values across the hand and wrist joints of twenty chronic stroke patients. The overall mean AROM of 19.6° with a standard deviation of 3.6° indicates that voluntary movement was significantly limited at baseline. This reflects severe impairment in active control of the hand and wrist prior to intervention. Across individual joints, flexion movements were relatively more preserved compared to extension and intrinsic movements. MCP and PIP flexion showed moderate values, while extension and intrinsic movements such as abduction and adduction were absent in most participants. This pattern reflects typical post-stroke motor impairment characterized by flexor dominance and reduced selective motor control. Distal joints such as the DIP showed reduced active motion, indicating greater difficulty in fine motor control. Wrist movements demonstrated relatively higher ROM compared to finger joints, although extension remained limited. Overall, table 1 confirms that participants began the intervention with substantial restrictions in voluntary hand and wrist movement, establishing a clear baseline for evaluating post-intervention changes.

Table 2 presents the pre-test Passive Range of Motion values across

Table 1: Mean and Standard Deviation of Pre-Test Active Range of Motion (AROM) Measurements Across Hand and Wrist Joints of Stroke Patients (n = 20).

Joint and Movement	Mean (°)	SD (°)
CMC Flexion	4.10	1.40
CMC Extension	6.90	4.30
CMC Abduction	6.10	2.30
MCP Flexion	58.50	6.20
MCP Extension	17.60	6.70
MCP Abduction	0.00	0.00
MCP Adduction	0.00	0.00
PIP Flexion	59.10	7.00
PIP Extension	0.00	0.00
DIP Flexion	43.00	6.20
DIP Extension	0.00	0.00
Wrist Flexion	42.30	5.80
Wrist Extension	17.30	4.20
Wrist Ulnar Deviation	25.60	4.70
Wrist Radial Deviation	14.30	4.60
Overall Mean and SD	**19.6**	**3.6**

Table 2: Mean and standard deviation of pre-test Passive Range of Motion (PROM) measurements across hand and wrist joints of stroke patients (n = 20).

Joint and Movement	Mean (°)	SD (°)
CMC Flexion	2.10	1.10
CMC Extension	7.60	4.40
CMC Abduction	2.70	1.20
MCP Flexion	15.00	2.90
MCP Extension	11.30	3.40
MCP Abduction	0.00	0.00
MCP Adduction	0.00	0.00
PIP Flexion	19.80	2.60
PIP Extension	0.00	0.00
DIP Flexion	13.30	3.30
DIP Extension	0.00	0.00
Wrist Flexion	70.70	16.80
Wrist Extension	7.20	2.10
Wrist Ulnar Deviation	21.60	18.80
Wrist Radial Deviation	5.20	2.20
Overall Mean and SD	**11.8**	**3.9**

the hand and wrist joints of chronic stroke patients. The overall mean PROM of 11.8° with a standard deviation of 3.9° indicates that passive joint mobility was also restricted prior to intervention, although slightly better than active movement. Compared to AROM, PROM values were generally higher, suggesting that joints retained some degree of mechanical mobility despite reduced voluntary control. However, several joints still showed severe limitations, particularly in intrinsic finger movements where abduction, adduction, and extension were absent. Wrist flexion showed relatively higher PROM compared to finger joints, indicating better preserved passive mobility at proximal structures. In contrast, distal joints demonstrated greater stiffness, reflecting soft tissue tightness and reduced joint flexibility. Overall, Table 2 indicates that although passive movement was present, joint stiffness and mechanical restrictions were already evident at baseline, supporting the need for an intervention aimed at improving both mobility and flexibility.

Table 3 presents the post-test data for the active range of motions across all joints of the wrist and hand. The overall mean active range of motion increased to 27.4° with a SD of 5.0°, signifying a notable improvement in voluntary movement capacity across all patients. Notable improvements were seen in wrist flexion and radial/ulnar deviation AROM - which approached its normal values, as well as the AROM of MCP and CMC joint motions which showed a twofold increase compared from the baseline data. Although flexion movements have shown substantial improvements in active range of motion, extension movements - particularly in PIP and DIP joints - as well as abduction and adduction movements at the MCP joint showed no improvements in the post-assessment data after soft robotic hand glove therapy. These findings suggest that increase in active ROM robotic hand-glove therapy effectively improved gross voluntary movements but had limited impact on intrinsic and extension-dominant actions within the intervention period - requiring a longer duration of intervention to achieve a more measurable date.

Table 3: Mean and standard deviation of post-test Active Range of Motion (AROM) measurements following a robotic hand-glove therapy intervention (n = 20).

Joint and Movement	Mean (°)	SD (°)
CMC Flexion	8.80	3.40
CMC Extension	12.50	5.00
CMC Abduction	9.50	3.30
MCP Flexion	75.20	7.60
MCP Extension	31.20	5.70
MCP Abduction	0.00	0.00
MCP Adduction	0.00	0.00
PIP Flexion	70.70	7.40
PIP Extension	0.00	0.00
DIP Flexion	54.40	6.60
DIP Extension	0.00	0.00
Wrist Flexion	61.90	6.90
Wrist Extension	36.10	20.30
Wrist Ulnar Deviation	33.50	6.10
Wrist Radial Deviation	17.50	3.00
Overall Mean and SD	**27.4**	**5.0**

Table 4: Mean and standard deviation of post-test Passive Range of Motion (PROM) measurements following a robotic hand-glove therapy intervention (n = 20).

Joint and Movement	Mean (°)	SD (°)
CMC Flexion	3.10	1.40
CMC Extension	13.30	5.30
CMC Abduction	4.00	2.60
MCP Flexion	19.20	5.00
MCP Extension	16.10	4.40
MCP Abduction	0.00	0.00
MCP Adduction	0.00	0.00
PIP Flexion	23.50	4.90
PIP Extension	0.00	0.00
DIP Flexion	18.20	3.80
DIP Extension	0.00	0.00
Wrist Flexion	65.50	27.00
Wrist Extension	16.30	19.80
Wrist Ulnar Deviation	21.00	6.50
Wrist Radial Deviation	6.50	1.50
Overall Mean and SD	**13.8**	**5.5**

Table 4 presents the post-test data for the passive range of motions across all joints of the wrist and hand. The overall mean passive range of motion increased to 13.8° with a SD of 5.5°, indicating that robotic hand glove therapy helped reduce joint stiffness and improved soft tissue compliance across all joints. Notable improvements were observed in CMC joint motions, indicating that robotic-assisted repetitive movement efficiently focuses on capsular tightness in larger joints. Similar to the active range of motion post-test data, passive MCP, PIP, and DIP joint flexion motions improved consistently, while extension., abduction. and adduction movements still showed no improvements. These findings suggest that although soft robotic hand glove therapy in passive ROM effectively reduced joint stiffness in major movement planes, it still had limited impact on intrinsic and

Table 5: Paired samples t-test analysis comparing pre-test and post-test Range of Motion (ROM) improvements following robotic hand-glove therapy (n = 20).

Joint / Movement	Type	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	*p*-value	Significant ($p < 0.05$)
CMC Flexion	AROM	4.10 ± 1.40	8.80 ± 3.40	<0.001	Yes
	PROM	2.10 ± 1.10	3.10 ± 1.40	<0.001	Yes
CMC Extension	AROM	6.90 ± 4.30	12.50 ± 5.00	<0.001	Yes
	PROM	7.60 ± 4.40	13.30 ± 5.30	<0.001	Yes
CMC Abduction	AROM	6.10 ± 2.30	9.50 ± 3.30	<0.001	Yes
	PROM	2.70 ± 1.20	4.00 ± 2.60	0.043	Yes
MCP Flexion	AROM	58.50 ± 6.20	75.20 ± 7.60	<0.001	Yes
	PROM	15.00 ± 2.90	19.20 ± 5.00	<0.001	Yes
MCP Extension	AROM	17.60 ± 6.70	31.20 ± 5.70	<0.001	Yes
	PROM	11.30 ± 3.40	16.10 ± 4.40	<0.001	Yes
PIP Flexion	AROM	59.10 ± 7.00	70.70 ± 7.40	<0.001	Yes
	PROM	19.80 ± 2.60	23.50 ± 4.90	0.001	Yes
DIP Flexion	AROM	43.00 ± 6.20	54.40 ± 6.60	<0.001	Yes
	PROM	13.30 ± 3.30	18.20 ± 3.80	<0.001	Yes

extension-dominant restrictions within the intervention timeframe.

Table 5 presents the statistical analysis comparing the pre- and post-test range of motion using paired t-tests. The paired t-tests signifies that the soft-robotic hand glove therapy showed notable and significant improvements ($p < 0.05$) in both active and passive ROM across all joints of the wrist and hand. Most notable improvements were observed at the MCP and wrist joints where active ROM improved almost twofold, suggesting a strong improvement in the neuromuscular control. Although active ROM showed a generally larger improvement, passive ROM mechanical changes still improved, suggesting enhanced voluntary control rather than passive stretching alone. Consistent overall findings between the pre- and post-test statistics across all joints of the wrist and hand suggest soft robotic hand glove therapy may be an effective tool for overcoming long-term physical plateaus of stroke patients and has helped in addressing both neural inhibition and joint stiffness - improving upper limb mobility.

Interpretation guide:

- Small: $d = 0.2$
- Moderate: $d = 0.5$
- Large: $d \geq 0.8$

Table 6 presents the effect size analysis using Cohen's d to determine the magnitude of change in range of motion across wrist and hand joints following soft robotic hand glove therapy. The findings suggest that the improvements did not just show statistically significant data, but are also clinically meaningful. Based on the findings and its interpretation, it showed large to very large effect sizes across nearly all joints - especially at the MCP joints. The large to very large effect size signifies that the robotic hand glove therapy showed substantial improvements rather than a chance. Large effect sizes in the thumb and distal finger joints shows that the intervention helped in addressing limitations in these areas especially in joints that are vital for functional hand use. Overall data supports the study's hypothesis, suggesting that soft robotic hand glove therapy is an effective intervention for improving hand and wrist mobility in chronic stroke patients.

Table 6: Effect Size (Cohen's d) of pre-test and post-test ROM improvements following robotic hand-glove therapy (n = 20).

Joint / Movement	Type	Mean Difference (°)	Cohen's d	Magnitude
CMC Flexion	AROM	+4.75	1.42	Large
	PROM	+1.00	0.82	Large
CMC Extension	AROM	+5.67	1.21	Large
	PROM	+5.75	1.18	Large
CMC Abduction	AROM	+3.41	1.10	Large
	PROM	+1.27	0.63	Moder ate
MCP Flexion	AROM	+16.64	2.30	Very Large
	PROM	+4.23	1.46	Large
MCP Extension	AROM	+13.63	2.07	Very Large
	PROM	+4.79	1.33	Large
PIP Flexion	AROM	+11.67	1.63	Large
	PROM	+3.70	1.08	Large
DIP Flexion	AROM	+11.40	1.78	Large
	PROM	+4.85	1.49	Large

Discussion

Prior to intervention, a significant gap between the available active and passive ROM across all participants were evident during the pre-assessment period, suggesting that the baseline data - shown in tables 1 and 2, solidifies that chronic stroke patients suffer from impaired voluntary control and emerging joint stiffness across all joints of the wrist and hand. The overall baseline assessment findings suggest that these limitations in the active ROM are caused by neural pathway damage rather than total joint immobility. After 20 sessions in 6 weeks of soft robotic hand glove therapy, post-assessment data was taken - presented in tables 3 and 4, has shown significant improvements both in active and passive ROM, with more notable changes present in gross flexion movements of the wrist, hand, and fingers, suggesting that robotic-assisted repetitive movement helps promote and facilitate motor relearning and reduces soft tissue limitations. Statistical analysis - shown in table 5, supports that these improvements were significant ($p < 0.05$), suggesting that the soft robotic hand glove therapy is effective and efficient in addressing neural inhibition and soft tissue resistance. Although the study showed significant improvements across all findings and has addressed recovery plateaus for gross movements, intrinsic movements limitations still remain after soft robotic hand glove therapy, suggesting that a relatively short intervention period has its limits - may not have been an enough duration to fully assess the long-term effect of the soft robotic hand glove therapy. Overall, the study showed significant improvements across all findings and has helped address recovery plateaus, suggesting that soft robotic hand-glove therapy effectively improved gross wrist and hand range of motion movements.

Conclusion and Recommendations

This study demonstrated that the robotic hand-glove significantly improved both active and passive range of motion in chronic stroke patients, particularly those with motor control impairments and joint stiffness, through assisted, repetitive movements. The study's intervention resulted in notable physiological and clinically meaningful benefits, such as enhanced joint flexibility, improved motor recruitment, and better overall functional hand use. It also improved patients' learned non-use by promoting voluntary movement. Although the results of this study are encouraging, extrapolation should be limited due to a small sample size, limited duration of implementation, absence of a control group, and the use of range-of-motion as the only outcome measure. The study concludes by recommending the inclusion of robotic-assisted therapy in rehabilitation programs, especially for patients who have had a chronic stroke, and also in the Philippine setting. It should focus on patient engagement, clinician adoption, and interdisciplinary collaboration, and calls for future research to involve larger samples, longer follow-ups, and more comprehensive functional outcome measures.

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