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Comparison between left and right hand after using of soft robot and rubber ball in patients with stroke: A Randomized control trail

Tameem T. Mayouf[*1], Mohammed B. Al-Jubouri[2]

[1,2]Department of Adult Nursing, College of Nursing, University of Mosul, Ninevah, Iraq.

https://orcid.org/0000-0002-4192-9583

Email ID: tameem.thamir@uomosul.edu.iq.

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ABSTRACT

Introduction: Stroke patients often experience hand function issues, affecting daily tasks and motor skills. Left or right hemispheric strokes may cause bilateral coordination issues. The study aimed to assess the difference between right- and left-hand outcomes according to the use of soft robot and rubber ball.

Methods: A randomized control trial was conducted from July 21 to November 20, 2024, dividing patients into two groups using robotic gloves and rubber balls. Twenty rehabilitation sessions were conducted over four months, with hand functions measured using the Action Research Arm tool.

Results: The study included 68 patients with an average age of 60.13 years, over 60% of whom were right-handed. The soft robotic glove significantly enhanced gross finger and thumb movements, achieving a post-intervention score of 6.04. The overall ARAT score improved markedly, with patients using the glove scoring an average of 14.14 before the intervention, which increased to 28.50 for the left hand and from 15.23 to 30.14 for the right hand. Rubber ball users showed slight improvements for both hands. Males exhibited a stronger response in the right hand, while females responded better in the left. Both genders had similar average reflexes for each hand.

Conclusion: The average age of the patients was 60, and there were more males than females in both groups. The right hand improved at a higher rate than the left with both the soft robotic glove and rubber ball, and rehabilitation outcomes were better for men than women.

Keywords: *Hand, Robot, Rubber, Stroke, Randomized controlled trial.*

1. INTRODUCTION

A stroke is a disorder characterized by diminished or obstructed blood flow to the brain [1], resulting in damage to brain tissue and impairing brain function [2]. It mostly affects elderly adults [3], leading to considerable handicap marked by muscular weakness and limited mobility [1-6].

Most people who have had a stroke will have problems with their hands [4,7], which will make them less useful for daily tasks [7]. How much use they lose depends on how bad the problem is [8]. This impairment will alter hand function and impact the execution of daily tasks [7,8].

Hand function denotes the capacity to use one's hands in everyday actions, reliant on anatomical coordination, strength, and dexterity. The functionality of the hand encompasses individuals using their hands for an array of intricate motor abilities, including playing a musical instrument, pinching, and gripping [7].

Hand function refers to the ability to use our hands in activities of daily living [9], which is contingent upon anatomical coordination strength, and dexterity [10,11], the hand function includes Grasp [12,13], pinch and manipulation [13], People use their hands for a variety of complex motor skills, such as playing a musical instrument, pinching, and grasping [14]. After a stroke affects the motor system, patients frequently exhibit increased movement variability [8,9]. Regardless of coordination patterns, we observed inconsistencies in force regulation during bilateral motions [15]. After a stroke, the balance between the two halves of the brain changed, as did the direction of ascending pathways [16]. This showed that neurons changed during activity in both hemispheres [15,16]. Stroke patients, much like healthy individuals, face greater challenges executing anti-phase movements compared to in-phase movements [17]. In healthy people, the two hemispheres play different roles in these movements [16,17]. This means that people who have had left or right hemispheric strokes are

likely to have different problems with bilateral coordination [15]. However, it is still not clear how left and right hemisphere strokes specifically affect limb performance during bilateral movements [18]. This is because bilateral coordination depends on a complex system that includes both individual limb control and inter-limb coordination [16,18].

Rehabilitation methods can improve the hand strength such as rubber ball and robots [19], Patients with upper extremity paresis can benefit from using a rubber ball as an alternative for hand exercise [20], rehabilitation methods using a rubber ball effectively stimulate the muscles of the upper extremity (hand and wrist) [20], which increases muscle strength and improves hand function [19,20]. Patients with upper extremity weakness can benefit from using a rubber ball as an alternative for hand exercise [20,21], Squeezing the ball will stimulate the upper extremity's muscles including fingers, hands, and wrists [19-22].

2. METHODS

Study design: A randomized control trail was used to determine the differences in the improvement of the right and left hands when using a soft robotic glove or a rubber ball.

Participants: Stroke patients who visited the Mosul Center for Specialized Rehabilitation from July 21 to November 20, 2024, were included in this study, Figure 1 illustrates a flowchart showing the selection criteria and were defined as follows:

1. The participants were at least 2 weeks after the onset of stroke.

2. Patient's age ≥ 20 years old. 3. No visual deficit and able to understand and follow simple instructions.

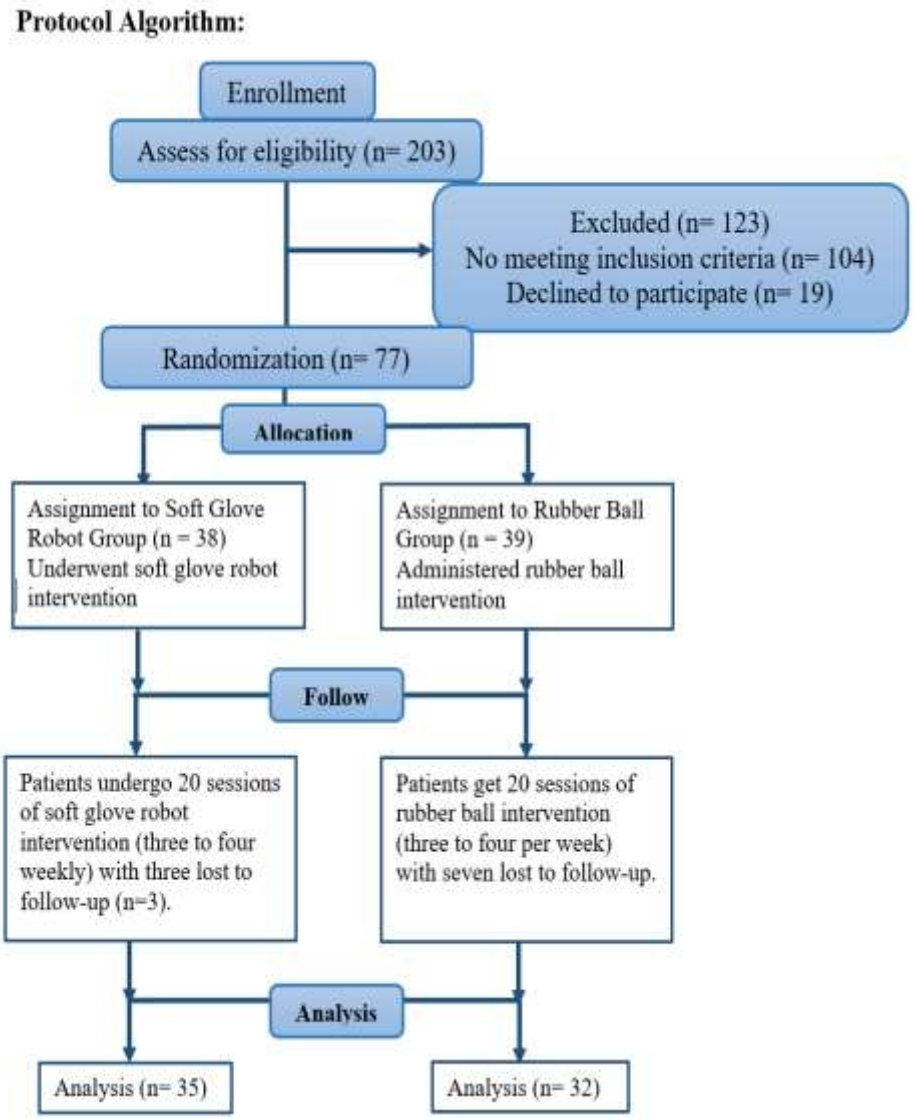

Figure 1: Flowchart for choosing samples in a randomexperiment (RCT).

Exclusion criteria: While the patients were excluded from study as follows:

1. Patients who have cognitive deficits, visual impairment and other medical disorders (tremors, diabetes).

2. Contractures of the affected upper limb interfering with positioning in the device. The study included 77 patients with both thrombotic and hemorrhagic strokes.

Sample size: The sample size was calculated with the Crossover Sample Size Formula. The patients were divided into two groups: one group of 35 patients used the robotic glove, and the other group of 33 patients used the rubber ball. The researchers interacted with the patients daily to remind them of appointments, monitor progress, and help with transportation expenses.

Ethical approval: The research received a license from the Iranian Registry of Clinical Trials (Approval number IRCT20240623062222N1 on July 15, 2024), in addition to ethical approval from the Ministry of Planning, the College of Nursing/University of Baghdad (Approval letter 03 on 07.05.2023), and the Nineveh Health Directorate committees (Approval Letter 23720 on 24.06.2024).

Outcome measurements: Twenty rehabilitation sessions over four months have been conducted for both groups underwent, with three or four sessions per week. The study measured hand functions using the Action Research Arm tool both before and after the intervention. This tool includes four sub-parts (grasp, grip, pinch, and gross movement), which were arranged according to the difficulty of performance from the most difficult to least difficult, thereby improving the efficiency of the test. The performance of each task was evaluated on four levels, ranging from zero, which indicates no movement, to three, which indicates normal movement execution, with a total evaluation full score of 57 points. After the patients were randomly assigned using the GraphPad program, they were monitored over the sessions

Statistical analysis: 12 patients were excluded from data analysis due to non-compliance with the rehabilitation program. The data were analyzed with the SPSS for Windows 11 ver. 27. Mean, standard deviation, and paired t-test were used to compare outcomes of two hands for both groups, A p-value below 0.05 was considered as significant differences.

3. RESULTS

The mean age of the 68 patients was 60.13, with males comprising over 65% and females over 25% in both groups. Additionally, more than 60% of the patients were right-handed, compared to 40% left-handed (Table 1).

Table 1: Demographic Characteristics of the Study Sample. N=68

Group		Glove group		Control group		Total
Variables		Mean	SD	Mean	SD	Mean
Age		59.91	60.00	59.48	58.00	60.13
Sex		N	%	N	%	Total
	Male	26	74.3%	21	63.6%	47
	Female	9	25.7%	12	36.4%	21
	Total	35	100%	33	100%	68
Site of Hemiplegia	Left hand	14	40%	12	36.4%	26
	Right hand	21	60%	21	63.6%	42
	Total	35	100%	33	100%	68

Patients using a soft glove robot exhibited a greater improvement in grasping power in the right hand (from 5.61 to 9.38) compared to the left hand (5.21 to 8.28), with significant differences observed between the two. Conversely, patients using a rubber ball showed no significant differences in grasping power between the right and left hands (Table 2).

Finger grip strength increases similarly in both hands when using a soft glove robot, achieving improvements of 7.07, with notable differences between the hands. In contrast, using a rubber ball leads to a maximum improvement of 6.64 in both hands, with no significant differences observed (Table 2).

Patients who used their thumbs and other fingers to pinch objects improved more than those who used a rubber ball, with a sub score of up to 8.09 for those who used the soft glove robot (Table 2).

Patients who used the rubber ball with both hands showed no significant improvement. In contrast, gross movements of the fingers and thumb improved significantly with the soft glove robot, scoring 6.04 post-intervention compared to 2.28 pre-intervention (Table 2).

The results showed a significant improvement in the total ARAT score. Patients using the soft robotic glove had an average score of 14.14 before the intervention, which increased to 28.50 for the left hand and from 15.23 to 30.14 for the right hand afterward. For rubber ball users, scores improved modestly and similarly for both hands, from 22.70 to 27.05 post-intervention (Table 2).

The study identified statistically significant differences between the left and right hands according to the ARAT total score in the soft robotic glove group ($p < 0.047$) but found no significant differences between the hands in the rubber ball group (Table 2).

Table 2: paired t-test analysis of variance for the differences between the right and left hand according to pre-intervention and post-intervention among two groups. N=68

Test		Soft Robot Group				Rubber Ball Group			
	Site	Left N= 14		Right N= 21		Left N= 12		Right N= 21	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
ARAT Grasp	Pre	5.21	4.28	5.61	5.46	6.20	2.17	5.94	2.81
	Post	8.28	4.33	9.38	5.33	7.26	2.52	7.00	2.78
P-value		0.0001*		0.0001*		0.224		0.047*	
ARAT Grip	Pre	3.14	2.38	3.28	3.36	4.86	1.64	5.23	2.41
	Post	7.07	2.64	6.61	2.76	6.40	1.91	6.64	2.49
P-value		0.0001*		0.0001*		0.051		0.125	
ARAT Pinch	Pre	3.50	3.50	3.76	4.15	5.66	2.60	5.70	3.49
	Post	7.78	3.14	8.09	3.92	6.66	2.38	6.58	3.10
P-value		0.0001*		0.0001*		0.458		0.115	
ARAT Gross Movement	Pre	2.28	2.58	2.57	3.02	5.06	2.08	5.82	2.92
	Post	5.35	1.73	6.04	2.10	6.60	1.99	6.82	2.42
P-value		0.021*		0.031*		0.539		0.814	
ARAT Total Score	Pre	14.14	10.76	15.23	15.44	21.80	7.03	22.70	10.07
	Post	28.50	10.42	30.14	13.58	26.93	7.74	27.05	9.84
P-value		0.0001*		0.0001*		0.034*		0.015*	

In the soft robotic glove group, males exhibited a stronger response in the right hand (33.67) compared to the left (29.73), while females showed a higher response in the left hand (24.00) than the right (21.33). In the rubber ball group, both genders had similar average reactions for each hand, with males averaging 28 and females reaching 25.57 (Table 3).

Table 3: paired t-test analysis of variance for the differences between right and left hand according to sex among two groups. N=68

Action Research Arm Test		**Glove Robot**		**Rubber Ball**	
		Left Hand	Right Hand	Left Hand	Right Hand
		Mean	Mean	Mean	Mean
Male	ARAT Pre	15.18	18.87	24.00	22.90

Female	ARAT Pre	10.33	6.17	18.50	22.43
Male	ARAT Post	29.73	33.67	28.78	28.10
Female	ARAT Post	24.00	21.33	24.17	25.57

4. DISCUSSION

The use of soft robots has significantly improved the grasping power of patients with right-hand hemiparesis compared to their left-hand post-intervention. This finding was also reported by a study that compared left and right hemiplegia in patients using a hand robot, which revealed that the left hand shows less improvement than the right [23].

The current study's findings contradict Lim's research, which suggested that individuals with left hemiplegia could stretch their fingers more effectively for gripping or releasing objects with their left hand than their right [24].

Several factors, including each person's reliance on one hand (dominant hand), may contribute to the difference in grasping abilities between the right and left hands. Previous studies investigating hand differences in healthy individuals have occasionally favored the right hand and, at other times, the left hand; this pattern has also been observed in other studies investigating hand grasping among patients [25-27].

The study found no variance in grip enhancement between the right and left hands, as both indicated significant improvement after the intervention. Comparison with other studies shows no differences between right and left hands regarding grip power [28, 29]. Two studies demonstrated greater improvements in grip strength for the right hand [30,26], while another reported better improvement in the left hand [31-34]. In a study on tennis players, Athletes, often favor their left hand over their right, making this preference more understandable [35].

The study showed a slight improvement in both hands regarding pinch scores, with the right hand showing marginally less advancement than the left among those using the soft robotic glove, while the group that used the rubber ball demonstrated no significant difference in pinch improvement between hands.

The use of the soft robotic glove resulted in an improvement in the accuracy of pinching tiny cubes or coins with both hands, with minimal differences [30]. While 13 patients with hemiplegia due to spinal cord injuries were rehabilitated using a robotic glove, it was found that the left hand responded better to improvements in the rate at which they pinched small objects than the right hand [25]. The most important finding is that 49% of the overall improvement in both hands after 6 months was due to better pinching, as measured by the ARAT subscales. This was consistent for 18 people who had hemiplegia after a chronic stroke [32].

This study found that the soft robotic glove notably improved gross motor movements in the right hand, exhibiting more rapid enhancement than the left. Both hands showed significant progress. Additionally, the use of a rubber ball greatly enhanced gross movements in both hands, with no noticeable differences in improvement levels.

When stroke patients used functional exercise for 4 weeks, the mean score for the gross sub score of ARAT was better than the right hand's, resulting in a total improvement of 11% for both hands [32,33]. A further study measuring motor weakness and enhancement using robot-mediated rehabilitation methods revealed no significant differences in gross movement across both hands [31]. In line with previous research, robotic gloves greatly improved hand function in spinal cord injury patients while they lifted both heavy and light cans. This showed that it could increase hand strength and make large motor tasks easier [25]. Another study was conducted at the Neurological and Rehabilitation Department using the ARAT instrument to assess enhancements in stroke patients, which demonstrated statistically significant differences in gross movement in both hands [29].

The total evaluation of the ARAT revealed that the right hand improved more with the use of the soft robotic glove than the left, with the post-intervention showing double the improvement compared to the pre-intervention. This is in contrast to the use of the soft robotic glove with the rubber ball, which demonstrated significant improvements in both hands at comparable rates. Studies show that most hemiplegia patients are right-sided and need more rehabilitation time, but they tend to improve more effectively than those with left-sided hemiplegia [34,23]. Studies have used the rubber ball as an intervention or as a control group on stroke patients. The results showed that both hands got better, with only minor differences between them. The improvement in both hands was statistically significant [34,35]. While the soft robotic glove was used in other studies conducted to rehabilitate hand weakness after strokes, it had a statistically significant effect on both hands based on the ARAT scale [31,36]. Previous studies on rehabilitation exercises showed that the ARAT tool's total score—which includes grasp, grip, pinch, and gross movement—improved the abilities of stroke patients. The improvements were similar for both hands, and the differences were statistically significant [29,32,33].

The current study revealed that the men who used the soft robotic glove or the rubber ball showed a higher level of improvement than the women who used one of the interventions. Prior studies that have noted the use of rubber balls to

enhance grip strength in stroke patients showed that men improved more than women [21]. Another found that male students had a higher average hand grip strength than female students [26]. Males with hemiparesis or hemiplegia show more improvement than females in hand function performance after functional exercises [7,37]. As for women, their superiority over men in improving hand functions after four weeks of performing functional exercises was evident [33].

This study is the first to compare right- and left-hand use of soft robots and rubber balls in stroke patients. Results indicate that men responded more strongly than women across both groups. In the soft robotic glove group, men showed a greater response with their right hand, while women had a higher response with their left hand. This study faced limitations due to low patient commitment to multiple sessions, and all participants were hemiplegic, with most being right-hand dominant.

5. CONCLUSION

The research showed that patients using a soft glove robot experienced a greater improvement in right-hand grip strength compared to the left, with notable differences observed. Grip strength in both hands increased, but significant disparities were particularly evident when patients used their thumbs and fingers for pinching, showing more improvement than those using a rubber ball. With the glove, there were substantial gains in gross motor functions of the fingers and thumb. Statistically significant differences were found in the ARAT scores between the left and right hands in the soft glove group, while the rubber ball group showed no significant differences.

What is already know on this topic

Differences in recovery between the left and right hands, considering factors like hand dominance and hemispheric specialization.

What this study adds

Limited researches available which directly compare soft robotics to traditional hand exercises like rubber ball squeezing. The impact of hand dominance and stroke lateralization on rehabilitation

Competing interests

The author declares no conflict of interests.

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