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Original Article

Effectivity of Exoskeleton Robot-Assisted Therapy on Improving Muscle Strength in Post-Stroke Patients

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Abstract

Background : Upper limb weakness is the most disability caused by stroke. The availability of physiotherapists is still limited in Indonesia. The exoskeleton robot is a developing technology that involve in stroke rehabilitation therapy. The objectives of this study was to evaluate the effectiveness of exoskeleton robot–assisted therapy on improving muscle strength of patients after stroke.
Methods : An experimental study with two groups pre-test and post-test design carried out using consecutive sampling among stroke out patients at Diponegoro National Hospital (RSND) and William Booth Hospital (RSWB), Semarang. Patients in the robotic group (RG) (n=8) received 16 training sessions. Each session consists of 30 passive and ten active-weighted elbow flexion-extension with the exoskeleton robot. Meanwhile, the control group (CG) (n=8) received equivalent training of conventional therapy. The primary outcome of muscle strength was measured by Manual Muscle Testing (MMT) and handheld dynamometer. Pre and post-test MMT score data in each group were analyzed by Wilcoxon test, while handheld dynamometer score data were analyzed by paired t–test. Data between the two groups were analyzed by Mann–Whitney and unpaired t–tests.
Results : Significant improvements were shown for the MMT score (RG: p=0.014, CG: p=0.034). There were significant handheld dynamometer score improvements on muscle strength for elbow flexor and extensor in RG (p = 0.008 and p = 0.005 respectively) and in CG (p=0.036 and p=0.008 respectively). No significant difference in MMT and handheld dynamometer score between the two groups.
Conclusion : The exoskeleton robot-assisted therapy was as effective as conventional therapy for improving muscle strength in stroke patients.

Keywords : Exoskeleton robot, muscle strength, stroke

INTRODUCTION

Stroke is a syndrome that occurs suddenly due to the death of brain cells caused by reduced blood flow to the brain due to blockage or rupture of brain blood vessels.[1] Stroke prevalence in Indonesia increased from 7‰ in 2013 to 10.9 ‰ in 2018. Stroke has the highest mortality rate and the third leading cause of disability among the elderly after heart disease and diabetes mellitus in Indonesia.[2] Upper limb muscle weakness is the most common disability due to stroke.[3] The elbow plays such a significant role in performing upper limb function.[4] Muscle strength recovery carried out through rehabilitative intervention.[5] However, the availability of physiotherapist is still limited in Indonesia.[6] Exoskeleton robot device is one of the developing technology in stroke rehabilitation therapy. Robot-assisted therapy provides more effective motor function recovery compared to conventional.[7] Indonesian Ministry of Health targeted the 80% usage of technology for non-communicable disease treatment as one of the nine global targets for non-communicable disease management in 2025.[8]

The aim of the study was to evaluate the effectiveness of exoskeleton robot-assisted therapy on improving muscle strength of patients after stroke. This study hypothesized exoskeleton robot-assisted therapy has the same effectiveness with conventional therapy on improving muscle strength in post-stroke patients.

METHODS

This experimental study with two groups pre–test and post–test design was conducted in medical rehabilitation installation of RSND and RSWB from July to September 2020. The minimum sample needed is eight respondents each group according to a hypothesis test for the difference of means formula. Sixteen hemiparesis stroke patients selected through consecutive sampling and fulfilled the inclusion and exclusion criteria had been recruited as the study subjects. The inclusion criteria were 40–80 years old patients with ischemic or hemorrhagic stroke and a scale of 2–4 muscle strength based on Manual Muscle Testing (MMT). The subjects were excluded if they had cognitive impairment with a score of ≥ 23 on the Mini Mental State Examination (MMSE) or depression based on a score of ≥ 10 on Patient Health Questionnaire-9 (PHQ-9). After the patients gave verbal and written consent to participate in this study, they were divided into two groups, eight patients from RSND were in the robotic group and eight patients from RSWB were in the control group.

The materials used in this study include: exoskeleton robot, handheld dynamometer, MMSE and PHQ-9 questionnaires, stationery, ½ kilogram load, data sheet form for research subjects and measurement results. The RG received exoskeleton robot-assisted therapy, while the CG received conventional therapy. Both underwent the training for a total of 16 sessions, 2 session per week in eight weeks. A session of robotic training consists of 2 sets 3 rpm automatic mode, 1 set 4 rpm automatic mode, and 1 set of passive mode with 500 gram load with 10 repetitions per set. A session of conventional training consists of 3 sets of elbow flexion-extension passive movements and 1 set of elbow flexion-extension active movements with 500 gram load with 10 repetitions per set. All patients were evaluated at the beginning of the study and at the end of 16 sessions. The strength of elbow flexor and extensor muscles was measured by MMT and handheld dynamometer.

The intervention effects were assessed through statistical analysis by comparing the muscle strength improvement between RG and CG. Pre and post-test data of muscle strength based on MMT score in RG and CG were analyzed by Wilcoxon test due to the ordinal data scale in pair group. Meanwhile, pre and post–test data based on handheld dynamometer score in RG and CG were analyzed by paired t–test due to the numeric data scale with normal distributed data. Changes in the pre and post–test data for MMT score between the two groups were compared by Mann-Whitney test. Meanwhile, changes in handheld dynamometer score between the two groups were analyzed the independent t–test. The significance value is $p<0.05$.

This research was approved by the Health Research Ethics Committee of the Faculty of Medicine UNDIP and RSUP Dr.Kariadi Semarang No.79 / EC / KEPK / FK–UNDIP / V / 2020.

RESULTS

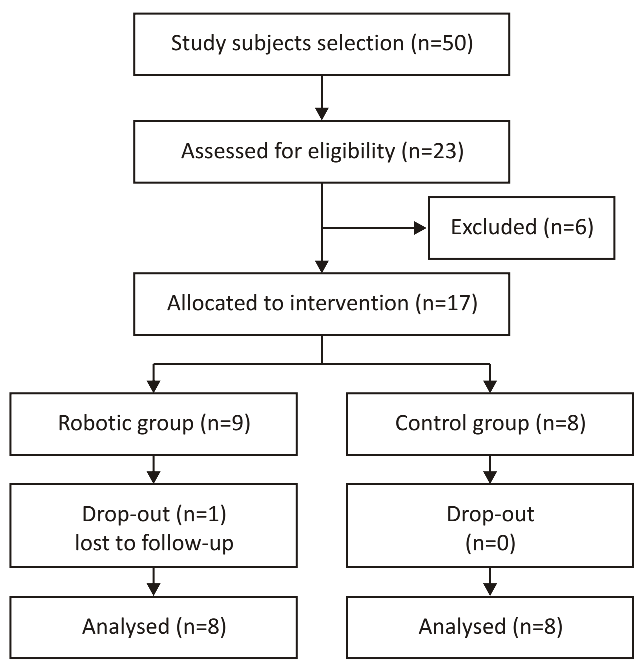

Figure 1. CONSORT flow diagram for each stage of study

TABLE 1
Demographic and clinical characteristics of study subjects

Characteristics		Robotic Group	Control Group		Comparison Analysis p
Stroke Type	Ischemic	7 (88%)	7 (88%)	14 (88%)	0.767[a]
	Hemorrhagic	1 (12%)	1 (12%)	2 (12%)	
Hemiparetic Limb	Right-sided	7 (88%)	4 (50%)	11 (69%)	0.141[a]
	Left-sided	1 (12%)	4 (50%)	5 (3%)	
Stroke Onset	Acute	0 (0%)	1 (12%)	1 (6%)	0.050[a]
	Subacute	1 (12%)	5 (63%)	6 (38%)	
	Chronic	7 (88%)	2 (25%)	9 (56%)	
Gender	Male	4 (50%)	6 (75%)	10 (62%)	0.304[a]
	Female	4 (50%)	2 (25%)	6 (38%)	
Age (year)	Mean	58	62.5	60	0.336[b]
	Median	60 (44–70)	62 (52–78)	61.5 (44–78)	
Comorbidity	Hypertension	7 (88%)	7 (88%)	14 (88%)	0.767[a]
	Diabetes Mellitus	2 (25%)	6 (75%)	8 (50%)	0.066[a]
	Ischemic Heart Disease	0 (0%)	1 (13%)	1 (6%)	0.500[a]
Recurrent Stroke		4 (50%)	3 (38%)	7 (44%)	0.744[b]

[a]Fisher's Exact Test, [b]Independent T-test

TABLE 2
The pre and post-test data in each group

Group	Muscle Measurement		Mean ± SD		p
			Pre-test	Post-test	
Robotic	MMT (grade)	Flexor	3.1 ± 0.76	3.9 ± 0.99	0.014[a]
		Extensor	3.1 ± 0.76	3.9 ± 0.99	0.014[a]
	Handheld Dynamometer (Kgf)	Flexor	3.0 ± 1.54	4.5 ± 2.32	0.008[b]
		Extensor	3.1 ± 1.73	4.4 ± 2.33	0.005[b]
Control	MMT (grade)	Flexor	3.4 ± 0.74	4.1 ± 0.99	0.034[a]
		Extensor	3.4 ± 0.74	4.1 ± 0.99	0.034[a]
	Handheld Dynamometer (Kgf)	Flexor	3.5 ± 1.85	4.6 ± 2.22	0,036[b]
		Extensor	3.9 ± 1.89	4.6 ± 1.94	0,008[b]

[a]Wilcoxon Test, [b]Paired T-test

Fifty hemiparesis stroke patients had screened for this study as potential participants based on physical therapy clinical records. Twenty three patients were match with the inclusion criteria and six patients were excluded due to the exclusion criteria. A total of 17 patients were eligible according to the inclusion and exclusion criteria. Between July to September 2020, 16 patients completed 16 training sessions. One patient was dropped out because of a loss to follow–up so only 16 patients could be analyzed (Figure 1).

There were no significant differences of the demographic and clinical characteristics between robotic

TABLE 3
Outcome comparison between the two groups

Muscle Measurement		Group	Delta score Mean ± SD	p
MMT (grade)	Flexor	Robotic	0.8 ± 0.46	0.902[a]
		Control	0.8 ± 0.71	
	Extensor	Robotic	0.8 ± 0.46	0.902[a]
		Control	0.8 ± 0.71	
Handheld Dynamometer	Flexor	Robotic	1.6 ± 1.19	0.599[b]
		Control	1.2 ± 1.29	
	Extensor	Robotic	1.2 ± 0.90	0.182[b]
		Control	0.7 ± 0.57	

[a]Mann–Whitney Test, [b]Independent T–test

group and control group (Table 1). Both robotic and conventional training significantly improved elbow flexor and extensor muscles strength measured by MMT and handheld dynamometer score (Table 2). The difference of pre–post test score of the elbow flexor and extensor muscles strength in stroke patientsafter exoskeleton robot-assisted therapy was as the same as conventional training (Table 3).

DISCUSSION

In this study, there were no significant differences of the demographic and clinical characteristics between RG and CG. We only have 1 robot so far so we have difficulty in randomizing the subject. However, eight patients in CG were trained by the same physiotherapist to reduce the bias. We also measured muscle strength using two parameter which are MMT and handheld dynamometer. The handheld dynamometer gave quantitative muscle strength result as an objective measurement to reduce the examiner's subjectivity in MMT measurement. All measurement were conducted in three times then we calculated the average muscle strength in each measurement. The study data showed that 8 weeks of both robotic and conventional therapy significantly improved MMT and handheld dynamometer score for elbow flexor and extensor muscles strength. No significant differences of improvement found in MMT and handheld dynamometer score between the two groups.

Neuroplasticity theory explains how elbow flexor and extensor muscles strength increases after rehabilitation. When the motor cortex in lesion area is stimulated, a response of potential interactive between synaptic connection over the brain occurs. Paresis side movement training with an exoskeleton robot requires complex muscles coordination. Therefore, the motor re-learning process, neural reconstruction, and re-innervation of denervated muscles occur. Motor training also prevents muscles atrophy.[9–13] The more movement repetition, the more transfer of glucose transporter type 4 to sarcolemma so that the glucose uptake muscles increases. It increases muscles mass.[14]

In a recent study, Joo Hwan J *et al*. concluded that MMT score of elbow flexor and extensor muscles increased in both the robot-assisted and conventional groups.[11] This study synergistic with Jiyu Z *et al*. reported an increase of MMT score for anterior tibial muscle in stroke patients using either a lower limb exoskeleton robot or conventional therapy.[13] Study by Michiel *et al*. showed no significant difference of walking speed in sub acute stroke patient received the combination of conventional and robot-assisted compared to conventional therapy only.[14] Tijana J *et al*. demonstrated a significant reduction of motor deficit in robot-assisted compared to convention therapy. In this study, 13 stroke patients in the subacute phase followed robotic training five days per week for three weeks. The primary outcome had measured by Fugl–Meyer Assessment.[15] High standard deviation, stroke onset and patients' nutritional status difference, comorbid factors, stroke recurrence, and social factors caused different results of these study.[16–20]

Study Limitations

This study has several limitations. First, pandemic coronavirus disease caused decreasing number of stroke patients receiving therapy at RSND and RSWB. It makes the small sample size in this study. Second, the absence of randomization in this study. Third, the authors could not control influencing factors such as stroke onset, size of the lesion, location of blood vessels occlusion in the brain, variations in daily activities, and differences in additional therapy.

CONCLUSION

The exoskeleton robot-assisted therapy was as effective as conventional therapy for improving muscle strength in stroke patients.

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