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RESEARCH **Open Access**

Finger Exoskeleton in Simple Motor Rehabilitation Therapy on Arm and Hand Muscle Ability of Post-Stroke Sufferers

Puspa Wardhani[1a*], Irma Triyani[1b], Fakrul Ardiansyah[1c], Filomena Adelaide de Matos[2d]

[1] Department of Nursing, Poltekkes Kemenkes Pontianak, Pontianak, West Kalimantan, Indonesia
[2] Department of Emergency and Critical Care Nursing, University of Algarve, Faro, Portugal

[a] Email address: puspawardhani8@gmail.com
[b] Email address: irma03triyani@gmail.com
[c] Email address: fakrul.ns@gmail.com
[d] Email address: fmatos@ualg.pt

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Abstract

Post-stroke sufferers will generally experience weakness on one side of the body, balance, vision, sensory, motor, and cognitive. In West Kalimantan, the estimated stroke sufferer in 2013 was 25,195 people. Based on data from the Public Hospital of Dr. Soedarso Pontianak shows a significant increase from January 2018 to December 2018 totaling 722 people. The research objective was to assess the effectiveness of the finger exoskeleton tool in simple motor therapy on the ability of the client's arm and hand muscles after a stroke. This study used a quantitative approach with a quasi-experimental design. Pre-test and Post-test Nonequivalent Control Group with two groups, which were the control group of 12 people and the intervention group of 12 people with finger exoskeleton tools. The statistical test used was the independent t test and paired t test. Measurement of muscle ability with the Action Research Arm Test. Analysis of the difference in total scores between before and after treatment in the intervention group using Paired T-Test obtained a p-value of 0.000 (p value <0.05) and in the control group using the Wilcoxon test a p-value of 0.016 (p value <0.05). It shows that there is a significant difference in the total score between before and after finger exoskeleton therapy and range of motion. Intervention of finger exoskeleton assistive devices in simple motor rehabilitation therapy is effective in increasing the ability of the client's arm and hand muscles after stroke. It is recommended to make another finger rehabilitation tool with a more optimal design according to the parameters, which are the severity of the client after stroke, subject kinematics, control of movement torque and adaptation between the subject and the robotic device used.

Keywords: Finger Exoskeleton, Muscle Ability, Post Stroke, Motor Rehabilitation.

Corresponding Author:

Puspa Wardhani
Department of Nursing, Poltekkes Kemenkes Pontianak, Pontianak, West Kalimantan, Indonesia.
Email: puspawardhani@gmail.com

1. INTRODUCTION

In the world, stroke is a deadly disease after heart disease and cancer. WHO estimates that the number of stroke patients in several European countries will increase from 1.1 billion per year in 2000 to 1.5 billion per year in 2025. In Indonesia, according to data released by the Post-stroke Foundation Indonesia, it shows a trend that is continues to increase from year to year (Utomo, et al., 2018). Cerebrovascular disease is the second leading cause of death and the third most common cause of disability in the world (Feigin et al., 2017).

In West Kalimantan, the estimated stroke sufferer in 2013 was 25,195 people. Data from hospitals in Pontianak City specifically for Public Hospital of Dr. Soedarso shows an increase from January to December 2018 totaling 722 people (Public Hospital of Dr. Soedarso, 2018). The impact of stroke on sufferers, among others, can damage the body, movement and speech ability, influenced by the damaged part of the brain. The special impact of hemiparesis is loss of body control in part. This ability will usually weaken daily activities (Mohan, et al., 2013). If there is movement, all the structures in the joint will be affected, which are the muscles, joint surfaces, joint capsules, fascia, blood vessels, and nerves (Minagawa, et al., 2015).

The main protocol for rehabilitation of post-stroke patients is based on learning movements which cause dendrite growth, new synapses, and good changes (Takeuchi & Izumi, 2013). The occurrence of motor defects in the upper and lower limbs after a stroke and damage to the motor cortex is common. Hemiparesis, paralysis, weakness, abnormal muscle tone, spasm, abnormal posture, abnormal synergistic muscle function, and loss of inter-joint coordination are the most common injuries resulting from damage to the motor cortex due to stroke (Kato & Izumiyama, 2010). Eighty percent of patients who experience acute upper limb paresis after stroke, only a third achieve restoration of normal limb function back to normal (Carrera & Tononi, 2014)

Rehabilitation is a form of integrated therapy services which includes medical, psychosocial, educational, vocational approaches involving doctors, neurologists, medical rehabilitation doctors, nurses, physiotherapists, occupational therapy, medical social workers, psychologists and clients as well as family roles to achieve most functional abilities and prevent repeated stroke attacks (Utomo et al., 2018). Hand rehabilitation is essential for the restoration of independence in the activities of daily life for individuals who exhibit disability in the upper extremities. There is preliminary evidence that robotic devices with a force control-based strategy can assist in the effective rehabilitation of human limbs (Agarwal et al., 2015). Finger damage after stroke causes significant deficits in hand manipulation and daily task performance. Recent advances in rehabilitation robotics have demonstrated the increasing efficacy of rehabilitation. However, devices currently created do not have the capacity to accurately interact with the human finger at a level of speed and torque comparable to the performance of everyday hand manipulation tasks (Cafolla & Carbone, 2014).

Several recovery/rehabilitation therapies for stroke clients include ROM, Core Stability exercise, and CIMT (Constraint-Induced Movement Training) and robotic Arm (Exoskeleton active/passive) training has been used in physical therapy. However, the use of existing robotic-based therapies requires large funds, self-rehabilitation centers, specific operators, and difficult treatment for sensitive components (Rippun, et al., 2016).

The exoskeleton is a tool for physical therapy exercises which are generally used to help relieve a person's movement, especially in the world of construction, but exoskeleton is also used for medical purposes. Physical therapy exercises that are routinely conducted by stroke sufferers have successfully shown positive results in the form of increased lower limb ability, functional mobility (balance and walking) and quality of life.

Starting from the above problems, the researchers took the initiative to create a simple tool that can be used to measure the client's gripping ability and help recover it. This simple tool is a prototype tool that has never been made before, so it is expected to be a new breakthrough in helping post stroke clients. A simple tool made with gloves using a battery or recharging the charger. In this study, the researchers took non-hemorrhagic stroke study material because it was possible for this patient to be given training with a finger exoskeleton in simple motor rehabilitation therapy using automatic gloves. It is hoped that in the future, the number of stroke sufferers will be increasing day by day, without knowing the socioeconomic status of the affected person will be able to improve the quality of life better with appropriate rehabilitation therapy and better than traditional therapy with the aim of improving movement function or maximum activity starting with hand movements. The method used in this study can easily be administered regularly in stroke patients by clients and families and it is easy to assess the progress of post-stroke patient health. The objective of this study was to determine the effectiveness of finger exoskeleton tools in simple motor rehabilitation therapy on the ability of arm and hand muscle function of post-stroke sufferers.

2. RESEARCH METHOD

The research method used in this research is a quasi-experimental with the pre-test approach and the post-test Nonequivalent Control Group approach. This research was conducted at the Public Hospital of Dr. Soedarso Pontianak from May to the end of October 2019. This research has received ethical approval from the ethics commission of the Health Polytechnic of the Ministry of Health Pontianak number: 186/KEPK-PK.PKP/V/2019. The population in a month of stroke sufferers is 60 people. Sampling is calculated based on the formula for estimating the sample size of the hypothesis test on the mean of two independent populations. The inclusion criteria in this study were patients diagnosed with non-hemorrhagic or hemorrhagic strokes who had physical disabilities in the upper extremities, while the exclusion criteria in this study were patients with severe stroke who experienced cognitive impairment. The sample size was 16 people divided into 2 groups, which were 8 people in the intervention group and 8 people in the control group.

The instrument used in this study was to measure the client's gripping ability after a stroke. Measurement/test of arm and hand function or measurement of grip function using the Action Research Arm Test instrument. This instrument consists of sub tests: a. Hold (grasp) with the highest score of 18 and each test is worth 3, b: Holds with the highest score of 12, with each test worth 3, c. Pinch with the highest score of 18 and each test is worth 3 d. Movement (Gross Movement) with the highest score of 9, with each test worth 3. The range of scores is 0-57 (Lesmana, 2014).

The univariate analysis in this study were variables of age, gender and variables of the arm and hand muscles of post-stroke patients. Nominal scale variable data (gender) is presented in the form of a percentage and the numerical scale variables (age) are presented in the form of mean and standard deviation. This univariate test was also conducted to determine the equality of age and sex characteristics of respondents between groups using the chi-square test. the equivalence test was administered to see the homogeneity of the two groups based on the characteristics of age and sex. The bivariate analysis in this study was the difference in the Action Research Arm Test scores between before and after exoskeletal finger intervention in the intervention and control groups. The statistical test used in this study was the independent t-test which was used to analyze the difference in scores before the intervention between the two groups and the difference in scores after the intervention between the two groups (unpaired), while to test the difference in scores before and after the intervention was conducted. In both groups (paired data), the Paired t-test was used.

3. RESULTS AND DISCUSSION

Table 1. Characteristics of respondents based on gender and age at the Public Hospital of Dr. Soedarso Pontianak in 2019 (n = 16)

Characteristic	Respondent based on genders				*p-value*
	Intervention group		Control group		
	F	%	F	%	
Gender					
Male	6	75	1	12,5	0.041
Female	2	25	7	87,5	
Age (Year)					
40-50	4	50	0	0	0,077
51-65	4	50	8	100	

** Chi-Square Test*

Table 1 shows the characteristics of the respondents based on gender and age mostly were men in the intervention group at 75% while the control group was mostly women at 87%. The results of the equivalence test obtained a p-value of 0.041, which means that there is no significant gender difference between the control and intervention groups. Meanwhile, based on age, the age group was dominated by 51-65 years old in the intervention and control group with the highest percentage in the control group, which is (100%).

Table 2. The ability of the arm and hand muscles of stroke patients at the Public Hospital of Dr. Soedarso Pontianak in 2019 (n= 16)

No	Indicator	Min		Max		Mean		SD	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
1.	Holding	3	3	18	18	10,50	13,13	4,423	3,442
2.	Grasping	0	0	6	8	0,94	2,94	2,112	2,542
3.	Pinching	0	0	9	11	0,75	1,63	2,324	2,872
4.	Movement	0	0	9	12	0,94	1,31	2,620	3,281

Table 2 shows that the average holding ability has increased by 2.63, the grasping ability has increased by 0.88 and the hand movement has increased by 0.37.

Table 3. An overview of muscle ability scores before and after the intervention in the two groups (n=16)

Measurement	Mean	SD	Median (Min-Max)	*p-value**	Note
Pretest Intervention	12,00	4,24	12,00 (6,00-18,00)	0,273	Normal
Pretest Control	13,87	11,77	9,00 (6,00-39.00)	0,006	Not Normal
Posttest Intervention	16,87	4,22	16,50 (12,00-24,00)	0,557	Normal

Posttest Control	21,12	13,22	18,00 (6,00-49,00)	0.173	Normal

**Data Normality Test Using Saphiro-Wilk Test*

Based on table 3, it can be seen an overview of the muscle ability scores before and after being given to the two groups where the intervention group was given finger exoskeleton therapy and the control group was given Range of Motion therapy. In the intervention group, before being given treatment, the average value was 12.00 with SD 4.24 after being given the treatment, the average value was 16.87 with SD 4.22. In the control group, before being given the treatment, the average value was 13.87 with SD 11.77 and after being given treatment, the average value was 21.12 with SD 13.22.

Table 4. Analysis of Differences in Muscle Ability before and after treatment in the two groups (n=16)

Muscle ability	Pretest			Post-test			*p-value*
	Mean	**SD**	**CI 95%**	**Mean**	**SD**	**CI 95%**	
Group							
Intervention	12,00	4,24	8,45-15,54	16,87	4,22	17.32 -23.07	0.000
Control	13,87	11,77	4,02-23,72	21,12	13,22	10,06-32,18	0.016

Information:
1. Difference between pretest and posttest in the intervention group using Paired T-Test (0.000)
2. Difference between pretest and posttest in the control group using the Wilcoxon Test (0.016)

Table 4 shows the differences in muscle ability before and after treatment in the two groups. From statistical calculations to compare the pretest and posttest in the intervention group using Paired T-test, the p-value is 0.000, which means that the value is smaller than the significance value set by the researcher, which is 0.05 (p-value <0.05), so it can be concluded that there is differences in muscle ability in patients before and after being given finger exoskeleton therapy treatment.

Statistical calculations to compare the pretest and posttest in the control group using the Wilcoxon test obtained a p-value of 0.016, which means that this value is smaller than the significance value set by the researcher, which is 0.05 (p-value <0.05) so it can be concluded that there are differences in muscle ability. in patients before and after given range of motion therapy treatment.

Table 5. The Difference Difference in Increasing Muscle Ability Score Before and After being given treatment (n=16)

Measurement	Mean Difference	Median	SD	Std Error	Shapiro-Wilk	Nilai p
Intervention	4,87	6,00	1,55	0,548	0,000 (Normal)	0.161*
Control	7,25	6,00	4,30	1,520	0,367 (Not Normal)	

* Mann-Whitney Test, (p-value>0.05)

Based on table 5 above, it can be seen the difference in the difference in muscle ability scores using the Mann-Whitney test. The results of statistical calculations obtained p-value 0.161, which means that this value is greater than the significance value set by the researcher, which is 0.05 (p-value>0.05). It shows that there is no significant difference between the two groups' muscle ability scores, so it can be concluded that finger exoskeleton therapy and range of motion have a positive effect on increasing the ability of the hand and arm muscles.

The statistical test results of the difference between the total pre and post test scores in the control group obtained p value = 0.016 where p<α, so it can be concluded that there is a difference between the total pre and post scores in the control group Range of Motion (ROM), and after treatment in the intervention group which was conducted by statistical test paired t-test resulted in a probability value of 0.000 (p value <0.05). Meanwhile, the control group produced a probability value of 0.016 (p value <0.05). The results of this analysis indicate that both finger exoskeleton therapy and range of motion therapy have a significant effect on the process of strengthening the hand and arm muscles of stroke sufferers. These results indicate finger exoskeleton therapy is a fairly good therapy in increasing the strength of the arm and hand muscles of post-stroke sufferers. The statistical test using Mann Whitney showed that there was no significant difference in the total score difference between before and after treatment between groups which had a probability value of 0.161 (p value <0.05). The statistical test using the independent t-test resulted in a probability value of 0.401 (p value> 0.05), which indicates that there was no significant difference in the total score after treatment between the two groups. It is influenced by the inequality of the total score before treatment between the two groups which has a probability value of 0.000 (p value> 0.05). It is due to the short research time so that the researcher had difficulty getting respondents according to the inclusion criteria and the number was limited and the collection of respondents with treatment time that could not be estimated when a stroke occurred.

The analysis of the difference in the total score between before and after treatment in the intervention group was conducted by using the paired t-test statistical test resulting in a probability value of 0.000 (p value <0.05). It shows that there is a significant difference in the total score between before and after giving finger exoskeleton therapy in the intervention group. Meanwhile, the control group produced a probability value of 0.016 (p value <0.05), which indicates a significant difference in the total score between before and after treatment in the control group. The results of this analysis indicate that the implementation of range of motion therapy has an effect on the recovery process of arm and hand muscle strength for stroke sufferers.

Based on the results of this study, patients who experienced non-hemorrhagic stroke (NHS) based on gender were mostly men in the intervention group by 75%, while the control group had the highest number of women at 87.5%. Cumulatively, non-hemorrhagic stroke patients are almost equal between men and women. These results are in line with research conducted by (Haast, et al., 2012) which explains that the prevalence of stroke in the world was 3% in 2008, which was more common in men. However, with age, a person's risk of having a stroke increases, both for men and women. At the age under 84 years, stroke is more common in men. Meanwhile, at the age above 85 years, stroke is more common in women.

Research (Ghani, et al., 2016) gained different results, where the sample size of women is slightly more than men. However, the proportion looks the same between men and women, which is 1.2%. The results of this study are in accordance with what was conveyed (Kes, et al., 2016) that older stroke patients, especially women, had worse disability on discharge from the hospital possibly due to older age at stroke. Younger patients recover better, while older patients should seek secondary medical facilities more frequently, as might be expected. The most important in-hospital laboratory findings in young stroke patients are elevated lipid levels, while older patients have elevated serum glucose and C-reactive protein. Stroke attacks in younger patients most often present with sudden headache. Furthermore, the onset attacks were more frequent than expected. Analysis of stroke risk factors showed that women were more prone to hypertension, chronic heart failure and atrial fibrillation, while men had carotid disease more frequently, smoked more frequently and had higher alcohol intake. Moreover, the age analysis showed that heart conditions and smoking were more common among older stroke patients. This condition is thought to be related to lifestyle and related to other risk factors, which are smoking, alcohol consumption and dyslipidemia.

The results of the paired t-test statistical test of this study indicate that the results of the study at Dr. Soedarso showed a significant condition with a value of p=0.000 between before and after finger exoskeleton therapy in the intervention group. It is in accordance with research by Unaizah (UNAIR, 2018) regarding the Finger Exoskeleton Portable (F-One) where the finger exoskeleton can help the fingers to perform basic movements according to movement patterns by utilizing an EMG sensor which can tap muscle signals. The muscle signal will be processed by an intelligent system using an Artificial Neural Network (ANN). Other research results related to this study are the results of research (McConnell, et al., 2017) which explains that there are deficiencies in hand stroke rehabilitation that can be conducted in a household environment and monitors physical and neurological progress. This exoskeleton finger uses two methods, which are active and passive. The passive method is performed by showing the client how to perform rehabilitation using a 3D screen while the active method, the patient tries to open their own hands with a predetermined time, and the BMI (Brain Machine Interface) system will provide additional energy for this movement.

Rehabilitation is important so that patients can continue to complete daily tasks (Pinter, & Brainin, 2012). As many patients have difficulty exercising their own damaged parts of the body, continuous passive motion is used in conjunction with physical therapy. Passive movements reduce muscle spasticity and activate the sensorimotor cortex in chronic stroke patients (Szameitat, et al., 2012). There are devices that use directed servomotors either directly attached to the exoskeleton joint (Taheri et al., 2014; Ueki, et al., 2012) or connected via tendons (Jones et al., 2014). However, research for the hand usually finds a number of difficulties due to mechanical characteristics which is complicated of the hand including its relatively small size, high degree of freedom and complex structure. To conduct many activities at hand, most hand rehabilitation devices have been used (Iqbal, et al., 2014). Clinical trials have shown robotic-assisted hand therapy results in improved hand motor function after chronic stroke, with increased activity of the sensorimotor cortex for trained tasks (Hwang, et al., 2012; Takahashi, et al., 2008).

Another type of rehabilitation that is commonly conducted is Range of Motion (ROM) exercises. ROM is a basic technique used to assess movement and for initial movement into a therapeutic neural intervention program. If there is movement, all the structures in the joint will be affected, which are the muscles, joint surfaces, joint capsules, fascia, blood vessels and nerves (Minagawa, et al., 2015). As soon as the medical condition stabilizes, it immediately provided passive ROM exercises to keep the joints from stiffening. Passive ROM is a joint exercise using the power of another person. Due to medical reasons, stroke patients in the acute phase will be limited in their activities. However, limiting the activity will result in the joint not moving, and the effect of not moving the joint for a certain time is joint stiffness or limited ROM. In this phase, the nurse will move the joints in the hands and feet of the stroke patient to prevent joint stiffness or limited ROM.

The design of the finger exoskeleton in this study was adjusted based on the anatomy of the human hand, the kinematic structure, and the limitations of the system design objectives. The working system design is based on finger flexion and extension movements and is easy to operate and requires only on or turn. The off commands and finger flexion and extension data require no communication with the computer or with the patient. Meanwhile, the design/system of the tool used does not exceed 2 kg in weight. Stroke patients must be able to move their hands freely when wearing the system/device. It is hoped that with minimal design changes, the system should be suitable for a variety of hand sizes and be portable. The system needs to allow the hand to have a minimum of 15 degrees of freedom. The design of the device must be precise because the device must allow the patient to control the movement (flexion/extension) of the affected finger based on the motion of the finger that is not disturbed. The index, middle and pinky fingers have the same extension and flexion motion, and the same number of bones by the same movement mechanism (finger articulation).

The results obtained from the intervention group research with the finger exoskeleton included the first stage of the ability to do finger extension including the index finger, middle finger, ring finger and little finger. Furthermore, if the 4 fingers are open, an object such as a tennis ball is given to hold it, the fingers do not flex again. The results of measurements with ARAT (Action Research Arm Test), the highest average progress that can be achieved by stroke patients is grasping the block which is a score of 18 (total score 18), and the hardest to hold a stone. As for the point of grasping, almost all stroke patients cannot grasp with a score of 0 and after intervention, the patient can hold a medium-sized tube (2.5 cm in diameter) with a total score of 12. The ability to pinch before the intervention was obtained a score of 0 and after the intervention, the highest score for stroke patients that could be achieved was 3 (total score 18). The results of the movement (gross movement) of all stroke patients got a point value of 0 out of a total score of 9. As for the control group with the provision of Range of motion (ROM) therapy, the ARAT measurement results for holding items (grasp) obtained an average value of 18 (able to hold a 7.5 cm beam). The item holding the highest score obtained by stroke patients was 8, the pinching item got a score of 11 (able to hold a marble with the middle finger and thumb. For movement items (gross movement), the highest score was 3 (bringing the hand closer to the mouth).

The results of the study (Kim, et al., 2014) stated that after a passive ROM was performed on 37 post-acute stroke patients, they showed a significant increase in range of motion, upper limb function and daily activities compared to clients who did not undergo ROM action. Many important factors in improving limb function include knowing the degree of paralysis. The ability to speak and other abilities are an easy first step in correcting permanent paralysis. Before permanent paralysis occurs, 15 minutes of routine passive ROM exercises should be performed twice a day, five times a week for 4 weeks. After a stroke, the nerve function improves between 6-12 months. What is more important is the prediction of stroke improvement and minimizing permanence in clients (Kim et al., 2014). Clients who did not undergo ROM therapy showed edema and restriction of blood flow and spleen flow during the first 72 hours of occurrence up to 2-4 weeks.

The results of this study are also likely to be influenced by various external stimulus factors, including environmental stimulus factors such as the influence of local culture, age, gender, occupation, and the client's psychological status.

Anatomical healing through a neuroplasticity mechanism which includes collateral sprouting, which is a condition in which the normal nerve axons around the lesion will form synaptic branches with nearby degenerated nerve fibers. This collateral sprouting only occurs in axons that have the same target cells as axons that undergo degeneration (Petrina, 2014). This phenomenon is also called reactive synaptogenesis and also unmasking of the pathway, which shows the process of activating the multisynaptic latent pathway (which is not functioning in the previous state). lesions) but can be activated when the dominant pathway fails or is damaged (Petrina, 2014). Changes in neural plasticity are different from developing synapse rules. To be precise, information storage in neural networks is triggered by activities that continually alter synaptic efficacy. Taking into account the statements mentioned above, it can be concluded that motor experience, including rehabilitation interventions, greatly influences the post-stroke recovery rate.

4. CONCLUSION

The finger exoskeleton aid intervention in simple motor rehabilitation therapy is effective in increasing the ability of the client's arm and hand muscles after a stroke in Public Hospital of Dr. Soedarso Pontianak. It is recommended to make another finger rehabilitation tool with a more optimal design according to the parameters, which is the severity of the post-stroke client, subject kinematics, control of movement torque and adaptation between the subject and the robotic device used.

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