Medica Hospitalia
Journal of Clinical Medicine
Med Hosp 2024; vol 11 (3) : 264–270

OPEN ACCESS

Original Article

Comparison Between Robotic Finger Therapy Exercise and Conventional Exercise on the Range of Motion of the Metacarpophalangeal Joints: Study of Post-stroke Patients at Diponegoro National Hospital

Daniel Andry Kurniawan[1], Sri Wahyudati[1,3], Tanti Ajoe Kesoema[1,2], Hari Peni Julianti[1,2], Rahmi Isma Asmara Putri[1,2], Erna Setiawati[1,2], Dewi Kusuma Hartono[1]

[1]Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Diponegoro University, Semarang, Indonesia
[2]Medical Rehabilitation Installation, Diponegoro National Hospital, Semarang, Indonesia
[3]Department of Physical Medicine and Rehabilitation, Kariadi Hospital, Semarang, Indonesia

p-ISSN: 2301-4369 e-ISSN: 2685-7898
https://doi.org/10.36408/mhjcm.v11i3.1155

Accepted: July 04th, 2024
Approved: October 18th, 2024

Author Affiliation:
Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Diponegoro University Semarang, Indonesia

Author Correspondence:
Hari Peni Julianti
Dr. Sutomo Street 16, Semarang, Central Java 50244, Indonesia

E-mail:
hari_peni@yahoo.com

Abstract

Background : Metacarpophalangeal (MCP) joints range of motion (RoM) exercise can be done using either conventional exercise or robotic finger therapy. This study aimed to compare MCP joints RoM improvement between conventional exercise and robotic finger therapy exercise in post-stroke patients.
Methods : This study was a randomized controlled trial pre and post test controlled group design. The data were taken from individuals aged 45–65 years with a history of stroke undergoing medical rehabilitation at the Diponegoro National Hospital before and after intervention (robotic finger therapy exercise vs conventional exercise) for 6 weeks. MCP joints RoM was measured using goniometer before and after the intervention. Datas were analysed using SPSS ver 20.0. Normality of data distribution would be assessed using the Shapiro-Wilk test. Differences in the RoM of MCP joints before and after treatment in each group were tested using paired t-test. Group differences were tested using unpaired t-test.
Results : There was significant RoM improvement in each MCP joint in each group before and after the treatment (p<0.05). There was no significant difference in RoM improvement between groups (p>0.05).
Conclusion : Both robotic and conventional therapy significantly improve MCP joints RoM in post-stroke patients. There was no significant difference in MCP joints RoM improvements between robotic finger therapy and conventional exercise.

Keywords : conventional exercise, robotic finger therapy, metacarpophalangeal joints range of motion.

INTRODUCTION

The number of individuals suffering from stroke continues to increase. Based on *Riset Kesehatan Dasar* (RISKESDAS), the prevalence of stroke is currently 10.9%, increasing from the data in 2013.[1,2] In post stroke patients, metacarpophalangeal (MCP) joints range of motion (RoM) decreased due to spasticity of flexor synnergic pattern.[3]

Stretching is a general term used to describe any therapeutic maneuver designed to increase soft tissue elongation, thereby increasing flexibility by lengthening structures that have been shortened. Stretching exercises are very effective in reducing spasticity through tissue extensibility.[4] The elongation of collagen tissue can be maintained due to changes in the organization of collagen fibers and by changes in the viscoelasticity of collagen fibers that occur after continuous stretching.[5] Conventional exercise by repetitively moving joints through their full RoM aims to improve their RoM, but requires an one-on-one session with a therapist which limits its own availability (therapists as human resources).[6]

According to the American College of Sports Medicine, the recommended stretching exercise prescription for stroke patients is as follow. Type of exercise is passive static flexibility, with frequency of ≥ 2–3 times/ week, mild to intensity discomfort is felt in the stretched joint. Hold the stretch for 10–30 seconds, 2–4 repetitions for each stretch exercise.[7]

Robotic finger therapy is classified as therapeutic device meaning that the robotic device is expected to exert therapeutic effects. Robotic finger therapy is also classified as exoskeleton robotic device. To exert its therapeutic effect, robotic device needs to be secured around certain points on the body parts, hence the name exoskeleton. Robotic finger therapy can also be implemented to improve joint RoM by using same mechanism of action but without conventional exercise's limitation in human resource (therapist) availability.[6,8,9]

Currently there is no research comparing robotic therapy and conventional exercise in improving MCP RoM of post-stroke patients. This research aimed to determine the effectiveness and compare MCP joints RoM improvements between robotic finger therapy and conventional exercise in post-stroke patients at Diponegoro National Hospital.

METHODS

This study was carried out at Diponegoro National Hospital and was carried out from February to May 2023. This study was a randomized controlled trial pre test and post test controlled group design to determine the effect of finger therapy equipment training on the RoM of MCP joints in post-stroke patients. Participants in the intervention group performed robotic exercises 3 times a week for 6 weeks. The control group received conventional exercise 3 times a week.

The target population was individuals with a history of stroke. Inclusion criteria were as follows: (1) age 45–65 years; (2) diagnosed with stroke 6 months ago or more (chronic stroke) with weakness on one side; (3) Elbow flexor muscle strength with MMT > 3; and (4) Spasticity in the elbow joint (Tardieu scale <3). Exclusion criteria were as follows: (1) other neuromuscular diseases that can affect muscle tone; (2) systolic blood pressure > 160 mmHg and/or diastolic >100 mmHg; (3) there are contractures in the upper extremities, history of musculoskeletal injuries in both upper extremities; (4) there is dislocation or subluxation of the shoulder; (5) INA MoCA score < 26; (6) currently on antispastic therapy or other drugs that can affect muscle tone in the last 3 months; and (7) have uncorrected visual impairment. Drop out criteria were as follows: (1) failure to show to the therapy schedule more than 3 times non-consecutive or 2 times consecutively; and (2) did not come at the beginning and end of the research assessment. Subjects were recruited using consecutive sampling method then randomized into robotic therapy and

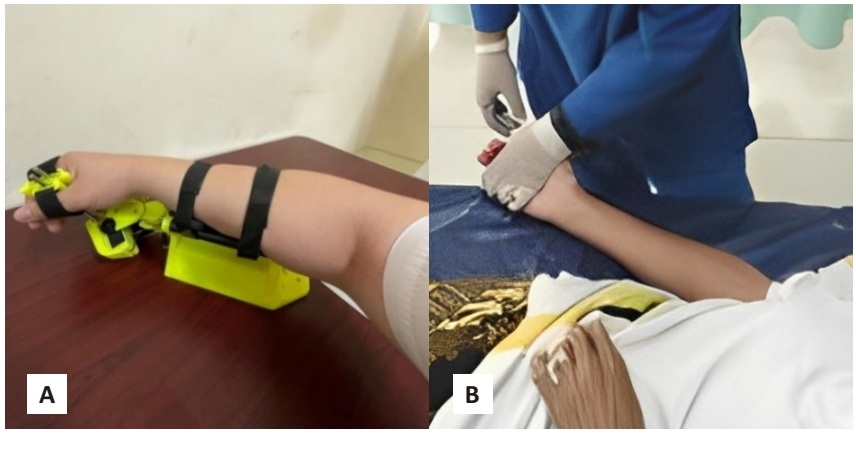

Figure 1. (A) Robotic finger therapy; (B) Conventional therapy

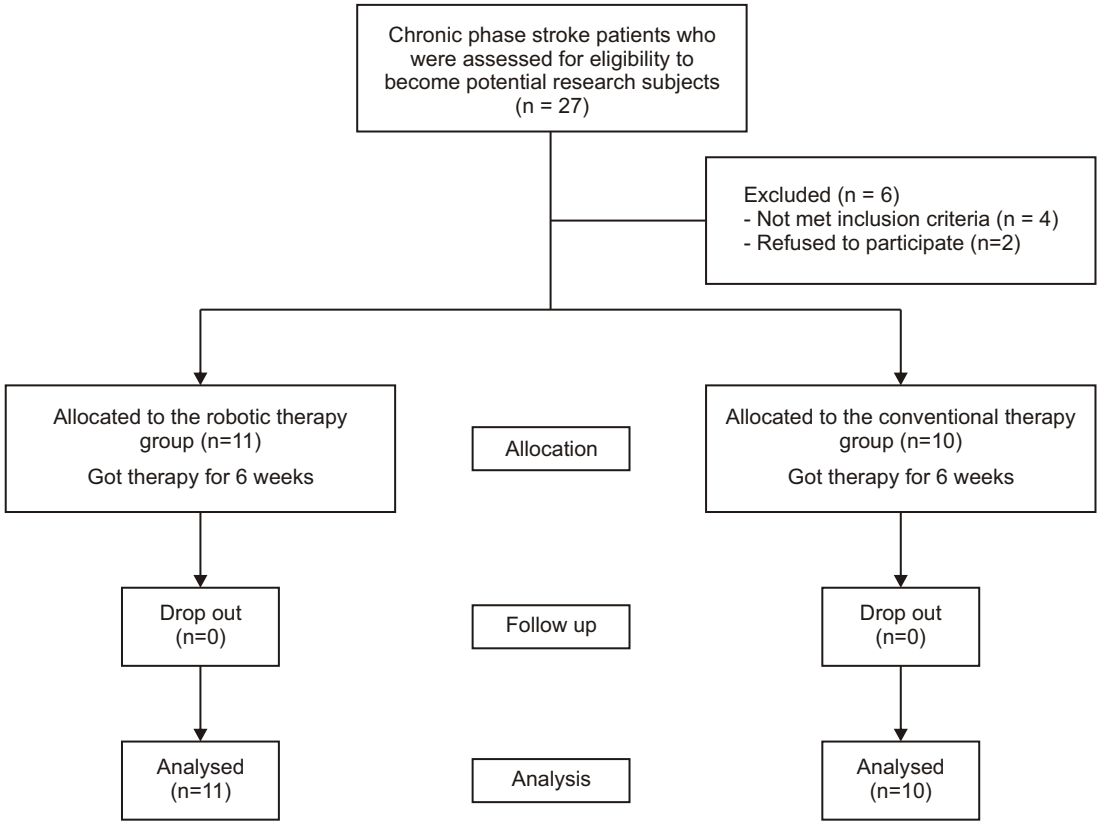

Figure 2. Consort diagram of data sample selection

conventional therapy group.

Robotic finger therapy has static part to support patient's lower arm and secure it with velcro. The moving (dynamic) part was the hand part. On the hand part there are two iron rods where plastic supports were installed. One plastic support would support digits II–V then tightened with velcro. The other plastic support would support digit I with the same mechanism. After the robotic device was turned on, the two plastic supports would move away from each other so that they provided an extension effect on the MCP I–V joints. Robotic finger therapy was given 3 times/week, with intensity until strech was felt on MCP joints (00 extension). 80 repetitions of extension were given with intervention time about 10 minutes.

Conventional therapy was carried out by therapist. Stretching exercise was given 3 times/week, with intensity until the strech was felt on MCP joints (00 extension). Each stretch was held for 10 seconds, then repeated stretch 10 times to conclude a set. A total of 2 sets were given in one therapy session.

MCP joints RoM was measured using goniometer before and after the intervention. MCP joints RoM was measured by same instrument and by principal investigator & research team. Data was collected in data collection sheets and coded, tabulated in the computer. Data analysis included descriptive analysis and hypothesis testing. Normality of data distribution was assessed using the Shapiro-Wilk test. *P* value of ≥ 0.05 showed that data was normally distributed.

The differences in the RoM of the MCP joints based on goniometer measurements before and after exercise in each group were tested using the paired t-test for data that was normally distributed and Wilcoxon test for data that was not normally distributed. The differences in the RoM of the MCP joints based on goniometer measurementus between groups that received robotic therapy and conventional therapy were tested using the unpaired t-test for data that was normally distributed and Mann-Whitney test for data that was not normally distributed. All data was processed with the help of a computer using SPSS® software ver 20.0. Significance in this study was obtained with a p value <0.05.

This study has been reviewed and approved by the Health Research Ethics Commission (KEPK), Faculty of Medicine, Diponegoro University with Document No. 123/EC/KEPK/FK-UNDIP/IV/2023.

RESULTS

Twenty seven datas of post-stroke patients were gathered. Six out of 27 were excluded due to failure to meet the exclusion criteria (n=4) and refusal to participate (n=2). The consort diagram of data sample selection was

shown in Figure 2.

Baseline characteristics of both groups were shown in Table 1. The table showed the results of the homogeneity test of baseline characteristics consisting of age, sex, duration from stroke onset, and stroke type. There was no significant difference between the robotic therapy group and conventional therapy group, with p-value >0.05. Demographic characteristics in both groups were homogenous.

Descriptive table and normality of MCP joints RoM before therapy were shown in Table 2. The table showed the results of the homogeneity test of RoM of MCP I-V before therapy in each group. There was no significant difference between of RoM of MCP I-V joints before therapy in conventional therapy group, with p-value >0.05. In robotic therapy group, significant differences were found for MCP II-IV joints, but no significant difference was found for MCP I & V joints.

The analysis of MCP I joint RoM improvement before and after therapy in each group and between group were shown in Table 3. Improvement of MCP I joint RoM before and after therapy both in robotic and conventional therapy group were found to be both significantly different (p<0.05). Improvement of MCP I joint RoM before and after therapy between robotic and conventional therapy group (improvement delta) was found to be not significantly different (p = 0.952).

The analysis of MCP II-V joint RoM improvement before and after therapy in each group and between groups were shown in Table 4–7. Improvement of MCP

TABLE 1
The baseline characteristics of data subjects

Variable	Group		p
	Robotic Therapy (11)	Conventional Therapy (10)	
Age (years)	57.27 ± 4.98	59.40 ± 6.08	0.217‡
Sex			0.562¥
Male	7 (50%)	7 (50%)	
Female	1 (25%)	3 (75%)	
Duration from stroke onset (months)	13.91 ± 5.30	20.30 ± 8.08	0.044§*
Stroke type			0.124¥
Hemorrhagic stroke	3 (100%)	0 (0%)	
Non hemorrhagic stroke	8 (44.4%)	10 (55.6%)	

*Significant (p<0.05); ¥Chi square; §Independent t; ‡Mann Whitney

TABLE 2
Normality of MCP joints RoM before therapy

Joint RoM	Group	Mean ± SD	Median (min–max)	p
MCP I (degree)	Robotic therapy	22.27 ± 12.72	20 (5–45)	0.345*
	Conventional therapy	26.50 ± 14.15	25 (10–55)	0.304*
MCP II (degree)	Robotic therapy	34.55 ± 30.29	25 (10–110)	0.008
	Conventional therapy	75.80 ± 24.83	77.5 (45–120)	0.499*
MCP III (degree)	Robotic therapy	39.55 ± 28.94	30 (20–115)	0.001
	Conventional therapy	81.00 ± 27.06	87.50 (40–120)	0.509*
MCP IV (degree)	Robotic therapy	40.45 ± 29.70	30 (15–120)	0.003
	Conventional therapy	77.00 ± 29.83	80 (30–120)	0.808*
MCP V (degree)	Robotic therapy	41.82 ± 24.73	40 (15–100)	0.156*
	Conventional therapy	76.00 ± 31.07	80 (20–120)	0.305*

*Normal (p > 0.05); £Shapiro–Wilk

TABLE 3
Analysis of MCP I joint RoM

MCP I RoM	Group		*p*
	Robotic Therapy (11)	Conventional Therapy (10)	
Pre test (degree)	22.27 ± 12.72	26.50 ± 14.15	0.480§
Post test (degree)	39.55 ± 8.50	44.00 ± 9.37	0.267§
P	<0.001¶*	<0.001¶*	
Delta (degree)	17.27 ± 7.20	17.50 ± 9.79	0.952§

*Significant ($p < 0.05$); §Independent t; ¶Paired t

TABLE 4
Analysis of MCP I joint RoM

MCP II RoM	Group		*p*
	Robotic Therapy (11)	Conventional Therapy (10)	
Pre test (degree)	34.55 ± 30.29	75.80 ± 24.83	0.007‡*
Post test (degree)	51.82 ± 24.73	94.00 ± 24.47	0.002‡*
P	0.001¶*	0.002¶*	
Delta (degree)	17.27 ± 12.32	18.20 ± 13.59	0.871§

*Significant ($p < 0.05$); §Independent t; ‡Mann Whitney; ¶Paired t

II-V joint RoM before and after therapy both in robotic and conventional therapy group were found to be both significantly different ($p<0.05$). Improvement of MCP II-V joint RoM before and after therapy between robotic and conventional therapy group (improvement delta) was found to be not significantly different. Improvement delta *p* values were 0.871, 0.359, 0.586, and 0.573 for MCP II–V respectively.

DISCUSSION

This study showed that there were significant improvements in MCP I–V joints RoM in both robotic and conventional therapy group before and after therapy. In the robotic therapy group, RoM increased by 17.27 ± 7.20, 17.27 ± 12.32, 18.18 ± 12.30, 17.27 ± 11.70, and 18.64 ± 12.06 for MCP I–V respectively. In conventional therapy group, RoM increased by 17.50 ± 9.79, 18.20 ± 13.59, 13.00 ± 12.95, 14.50 ± 11.17, and 15.50 ± 13.01 for MCP I–V respectively.

Underlying pathology in post-stroke spasticity showed that there was decrease hyaluronic in acid turnover, increase in intramuscular connective tissue deposition, and increase in extracellular connective tissue viscosity. Those three mechanisms will in turn reduce the threshold for stimulation of spindle in the muscle and decrease golgi tendon organ function leading to spasticity. In time, increase in viscosity of the loose connective tissue may cause decreased gliding between the layers of collagen fibers, which may be perceived by patients as stiffness.[10] Another mechanism of spasticity relates to postactivation depression. Postactivation depression is a phenomenon that controls the excitability of the stretch reflex acting at the spinal level without depending on supraspinal control. It appears to be independent of the influences exerted by rostral centres. In stroke patients, postactivation depression decreases due to limb immobilization.[11] Mechanisms behind stretching and mobilization can reduce spasticity are that the increased extracellular connective tissue spasticity can be counteract by stretching and limb mobilization can restore post active depression.[10,11]

There were no significant differences in RoM improvements between robotic and conventional therapy group for each MCP joint. Comparing MCP I RoM improvements between robotic and conventional therapy group yielded *p*-value of 0.952. *P*-values were 0.871, 0.359, 0.586, and 0.573 for MCP II-V RoM improvements between robotic and conventional therapy group respectively.

Those findings were in conjunction with some previous studies. The study by Francisco J Valero-Cuevas in 2016 showed inconclusive result comparing robot-assisted vs. conventional therapy in 77 patients who had had chronic motor impairment after a cerebrovascular

TABLE 5
Analysis of MCP III joint RoM

MCP III RoM	Group		*p*
	Robotic Therapy (11)	Conventional Therapy (10)	
Pre test (degree)	39.55 ± 28.94	81.00 ± 27.06	0.004‡*
Post test (degree)	57.73 ± 26.30	94.00 ± 25.69	0.005§*
P	0.001¶*	0.011¶*	
Delta (degree)	18.18 ± 12.30	13.00 ± 12.95	0.359§

*Significant ($p < 0.05$); §Independent t; ‡Mann Whitney; ¶Paired t

TABLE 6
Analysis of MCP IV joint RoM

MCP IV RoM	Group		*p*
	Robotic Therapy (11)	Conventional Therapy (10)	
Pre test (degree)	40.45 ± 29.70	77.00 ± 29.83	0.009‡*
Post test (degree)	57.73 ± 26.40	91.50 ± 29.54	0.018‡*
P	0.001¶*	0.003¶*	
Delta (degree)	17.27 ± 11.70	14.50 ± 11.17	0.586§

*Significant ($p < 0.05$); §Independent t; ‡Mann Whitney; ¶Paired t

TABLE 7
Analysis of MCP V joint RoM

MCP V RoM	Group		*p*
	Robotic Therapy (11)	Conventional Therapy (10)	
Pre test (degree)	41.82 ± 24.73	76.00 ± 31.07	0.011§*
Post test (degree)	60.45 ± 26.78	91.50 ± 27.79	0.017§*
P	0.001¶*	0.004¶*	
Delta (degree)	18.64 ± 12.06	15.50 ± 13.01	0.573

*Significant ($p < 0.05$); §Independent t; ‡Mann Whitney; ¶Paired t

accident.[12] Study by Cora Carrillo in 2023 revealed that the effects of robotic therapy and conventional therapy were similar, and that robotic therapy combined with conventional therapy was not superior to conventional therapy alone.[13]

The absence of significant differences between RoM improvements between robotic and conventional therapy group for each MCP joint can be explained by lack of therapy intensity, frequency and duration, especially for the robotic therapy group. The study by Nero Singh in 2021 comparing robotic and conventional groups for post-stroke rehabilitation, the protocol for the robotic group was 45-minute of individual sessions perday for 20 therapy sessions (5 days a week for 4 weeks). In this study, comparing active RoM improvements between robotic-therapy and control group, the difference was significant with *p*-value of 0.02.[14] Systematic review and meta-analysis by Lee Bih-O in 2023 evaluating robotic arm use for upper limb rehabilitation after stroke, the duration of the intervention varied from 3 to 5 times per week for 30 to 120 min per session. The duration of the intervention ranged from 3 to 12 weeks.[15]

However, there are some other aspects in which robot are better than conventional therapy. Robots can enhance existing conventional therapy by delivering a

precise and consistent therapy of highly repetitive movements. Robot assisted physiotherapy could facilitate the effectiveness of unsupervised rehabilitation and thus, may reduce the cost and duration of therapist-assisted rehabilitation.[16] Additionally, robotic rehabilitation can potentially increase patient motivation and engagement. It is worthy to note that the use of robotics for rehabilitation is viewed as acceptable, useful, and beneficial by patients and healthcare professionals.[17] This study had some limitations that might affect the study results. Sample size was relatively small, and protocols implemented in this study lacked in intensity, frequency, and duration.

CONCLUSION

Both robotic and conventional therapy significantly improve MCP joints RoM in post-stroke patients. There were no significant differences in MCP joints RoM improvements between robotic finger therapy and conventional exercise.

REFERENCES

1. Laporan Nasional Riskesdas 2018. Jakarta: Lembaga Penerbit Badan Penelitian dan Pengembangan Kesehatan; 2019.
2. Primadi O, Ma'ruf A, Indrayani YA, Wardah, Susanti MI, Pangribowo S, *et al*. Profil Kesehatan Indonesia 2020. Jakarta: Kementerian Kesehatan Republik Indonesia; 2021.
3. Cuccurullo SJ. Physical Medicine and Rehabilitation Board Review, Fourth Edition: Springer Publishing Company; 2019.
4. Kisner C, Colby LA, Borstad J. Therapeutic Exercise: Foundations and Techniques: F.A. Davis Company; 2017.
5. Ghasemi E, Khademi-Kalantari K, Khalkhali-Zavieh M, Rezasoltani A, Ghasemi M, Baghban AA, *et al*. The effect of functional stretching exercises on functional outcomes in spastic stroke patients: A randomized controlled clinical trial. J Bodyw Mov Ther 2018;22(4):1004–12. https://doi.org/10.1016/j.jbmt.2017.09.021.
6. Aman JE, Elangovan N, Yeh IL, Konczak J. The effectiveness of proprioceptive training for improving motor function: a systematic review. Front Hum Neurosci 2014;8:1075. https://doi.org/10.3389/fnhum.2014.01075.
7. Medicine ACoS, Liguori G, Feito Y, Fountaine CJ, Roy B. ACSM's Guidelines for Exercise Testing and Prescription: Wolters Kluwer; 2021. p.178–185.
8. Keeling AB, Piitz M, Semrau JA, Hill MD, Scott SH, Dukelow SP. Robot enhanced stroke therapy optimizes rehabilitation (RESTORE): a pilot study. J Neuroeng Rehabil 2021;18(1):10. https://doi.org/10.1186/s12984-021-00804-8.
9. Chang WH, Kim YH. Robot-assisted Therapy in Stroke Rehabilitation. J Stroke 2013;15(3):174–81.https://doi.org/10.5853/jos.2013.15.3.174.
10. Stecco A, Stecco C, Raghavan P. Peripheral Mechanisms Contributing to Spasticity and Implications for Treatment. Current Physical Medicine and Rehabilitation Reports 2014;2. https://doi.org/10.1007/s40141-014-0052-3.
11. Trompetto C, Marinelli L, Mori L, Canneva S, Colombano F, Traverso E, *et al*. The effect of age on post-activation depression of the upper limb H-reflex. Eur J Appl Physiol 2014;114(2):359–64. https://doi.org/10.1007/s00421-013-2778-5.
12. Valero-Cuevas FJ, Klamroth-Marganska V, Winstein CJ, Riener R. Robot-assisted and conventional therapies produce distinct rehabilitative trends in stroke survivors. J Neuroeng Rehabil 2016;13(1):92. https://doi.org/10.1186/s12984-016-0199-5.
13. Carrillo C, Tilley D, Horn K, Gonzalez M, Coffman C, Hilton C, *et al*. Effectiveness of Robotics in Stroke Rehabilitation to Accelerate Upper Extremity Function: Systematic Review. Occup Ther Int 2023;2023:7991765. https://doi.org/10.1155/2023/7991765.
14. Singh N, Saini M, Kumar N, Srivastava MVP, Mehndiratta A. Evidence of neuroplasticity with robotic hand exoskeleton for post-stroke rehabilitation: a randomized controlled trial. J Neuroeng Rehabil 2021;18(1):76. https://doi.org/10.1186/s12984-021-00867-7.
15. Lee BO, Saragih ID, Batubara SO. Robotic arm use for upper limb rehabilitation after stroke: A systematic review and meta-analysis. Kaohsiung J Med Sci 2023;39(5):435–45. https://doi.org/10.1002/kjm2.12679.
16. Nik Ramli NN, Asokan A, Mayakrishnan D, Annamalai H. Exploring Stroke Rehabilitation in Malaysia: Are Robots Better than Humans for Stroke Recuperation? Malays J Med Sci 2021;28(4):14–23. https://doi.org/10.21315/mjms2021.28.4.3.
17. Germanotta M, Cortellini L, Insalaco S, Aprile I. Effects of Upper Limb Robot-Assisted Rehabilitation Compared with Conventional Therapy in Patients with Stroke: Preliminary Results on a Daily Task Assessed Using Motion Analysis. Sensors 2023;23(6):3089.