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Meta-Analysis

Effect of Robot Assistive Therapy on Hand Functional Ability in Stroke Patients: Meta-Analysis

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ABSTRACT

Background: Stroke is a neurological deficit disease caused by bleeding or blockage of blood vessels in the brain which can cause disability or death. Vascular injuries cause various neurological disorders, motor disorders and functional disorders of the hands which are very necessary to carry out daily activities. Robot Assistive Therapy as a breakthrough in stroke rehabilitation technology can be used as an alternative therapy method for post-stroke rehabilitation. This study aims to determine the effectiveness of the use of robotic assistive therapy and conventional therapy on the functional abilities of stroke patients' hands.
Subjects and Method: This study used a systematic review and meta-analysis design using the PRISMA flowchart guidelines and the PICO model (Population = Stroke patients. Intervention = Robot Assistive Therapy. Comparison = Conventional therapy. Outcome = Hand functional ability). The article search process was carried out using databases from PubMed, Science Direct, AJOT, Springer Link, and Google Scholar. The keywords used are "Robot Assistive Therapy" AND "stroke" AND "hand function" AND "randomized controlled trial" AND "Fugl Meyer Assessment". The inclusion criteria in this study were full-text articles using the Randomized Controlled Trial (RCT) design from 2012 to 2022. The corresponding articles were then critically reviewed and analyzed using RevMan 5.3 software.
Results: A meta-analysis was conducted on 9 randomized controlled trials (RCTs) from Belgium, Italy, Japan, Germany, Lithuania and Switzerland with a total sample of 537 stroke patients. The results of the meta-analysis showed that there was no difference in effectiveness between the use of robot assistive therapy and conventional therapy in improving the functional abilities of stroke patients' hands (SMD= -0.02; 95% CI= -0.42 to 0.38; p= 0.930).
Conclusion: There is no difference in effectiveness between the use of assistive therapy robots and conventional therapy in improving the functional abilities of stroke patients' hands.

Keywords: robot assistive therapy, stroke, hand functional abilities, meta-analysis

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BACKGROUND

Stroke is the third cause of death in the world after coronary heart disease and cancer in both developed and developing countries. One in 10 deaths is caused by a stroke (AHA, 2021), World of Stroke Organization data shows that every year there are 13.7 million new cases of stroke, and around 5.5 million deaths occur due to stroke (Lindsay et al., 2019).

The occurrence of a vascular injury that reduces cerebral blood flow will cause various neurological dysfunctions and disabilities depending on the location of the lesion, the size of the area, and the amount of blood flow to the brain. One of the health problems that arise due to stroke is loss of voluntary control over motor movements. The most common dysfunction is hemiplegia (paralysis on one side) due to a lesion on the opposite side of the brain (Ojaghihaghighi et al., 2017). Hemiparesis or weakness on one side of the body is another symptom of motor dysfunction which can cause various obstacles in carrying out daily activities (Franceschini et al., 2018).

The main problem of post-stroke motor dysfunction is the presence of impaired functional ability of the hands, making it difficult to carry out daily activities, work activities and leisure activities (Mehrholz et al., 2018). The functional ability of the hand itself is the ability to use the hand to carry out daily activities in terms of anatomy, sensory, muscle strength, dexterity and hand coordination (Duruöz, 2019).

The main goal in stroke rehabilitation is the restoration of motor skills by undergoing repetitive, high-intensity exercises and using programmed activities that allow stroke patients to regain motor and functional abilities (Yakub, 2014), the use of Robot Assistive Therapy (RAT) or therapy with robotics into technology. which holds promise for the rehabilitation of patients with motor impairment caused by stroke (Bertani et al., 2017). Rehabilitation robots are designed to adapt to the patient's functional level and several types of robots can be used for stroke rehabilitation including assisting ADL (Activity Daily Living) and functional abilities and rehabilitation robots can also facilitate clinical assessments of improving hand functional abilities (Dehem et al., 2019).

This study aims to prove the effect of using Robot Assistive Therapy (RAT) on increasing the functional abilities of stroke patients' hands. The data obtained were analyzed using a systematic review and meta-analysis in an effort to obtain comprehensive results, by synthesizing the results of the main studies using RAT in post-stroke therapy.

SUBJECTS AND METHOD

1. Study Design

This research was conducted using a systematic review and meta-analysis with the PRISMA flowchart. Article searches were performed using the following databases: PubMed, Science Direct, AJOT, Springer Link, and Google Scholar. Keywords used: "robot assistive therapy" AND "stroke" AND "hand function", "randomized control trial" AND "Fugl Meyer Assessment".

2. Steps of Meta-Analysis

The meta-analysis was carried out through 5 steps as follows:

1) Formulating research questions using the PICO model (Population= Stroke patients. Intervention= Robot assistive therapy. Comparison= Conventional therapy. Outcome= Hand functional ability).
2) Searching for primary study research articles from electronic databases and libraries, ie
3) PubMed, Science Direct, AJOT, Springer Link, and Google Scholar.
4) Conducting screening and quality assessment of primary research articles.
5) Extracting and analyzing data into the RevMan 5.3 application.
6) Interpreting the results and draw conclusions.

3. Inclusion Criteria

Full text paper articles using randomized controlled trails (RCT) studies, the relationship size used was Standardized Mean Defference (SMD), the study subjects were

stroke patients aged > 17 years, robot assistive therapy intervention, and outcomes were functional abilities of the hands.

4. Exclusion Criteria

Articles excluded from this study were articles with a non-RCT study design, published before 2012, and articles not in English.

5. Operational Definition of Variables

Articles included in the study were adjusted to PICO. Article search was carried out by considering the eligibility criteria defined using the PICO model. The research population, namely stroke patients, used the Robot Assistive Therapy (RAT) intervention and the outcomes were improving the functional abilities of the hands.

Hand functional ability is the ability to use the hand to carry out daily activities which include sensory, strength, dexterity and coordination.

Robot assistive therapy is an innovative exercise-based therapy using robotic devices that allows the application of repetitive, intensive, adaptive and measurable physical exercises.

6. Study Instruments

The quality of the articles in this study was assessed using the Fugl-Meyer Assessment of Upper Extremity (FMA-UE) instrument

7. Data Analysis

The data were analyzed using the Review Manager application (RevMan 5.3) to calculate the effect size and heterogeneity (I^2). The results of data processing are presented in the form of forest plots and funnel plots.

RESULTS

The review process was carried using the PRISMA flowchart which can be seen in Figure 1. Research related to the use of assistive therapy robots for functional abilities of the hand, a total of 9 articles obtained out of a total of 645 articles published after deletion obtained 21 articles and articles that met the quality requirements as many as 9 articles will be included in the quantitative synthesis using meta-analysis.

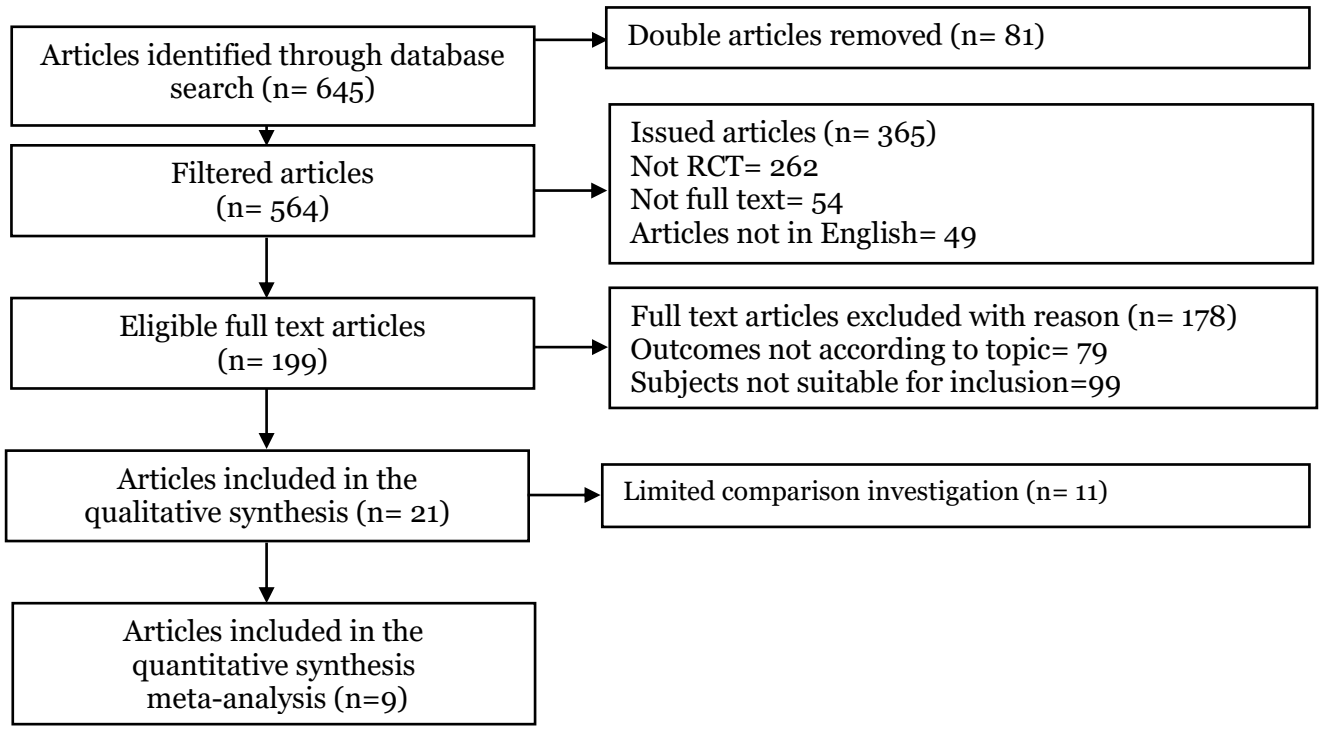

Figure 1. PRISMA Flowchart

Figure 2. Map of the research area of the effect of assistive therapy robots on the functional abilities of stroke patients' hands

It can be seen in Figure 2. That research articles originating from the European continent include Belgium, Italy, Germany, Lithuania and Switzerland while those from the Asian continent originate from Japan.

Table 1. Critical review of the effect of using Robot Assistive Therapy on the functional abilities of stroke patients' hands

Author (Year)	Question Criteria											
	1	2	3	4	5	6	7	8	9	10	11	Total
Aprile et al. (2020)	1	1	1	1	1	1	1	1	1	1	1	11
Carpinela et al. (2020)	1	1	1	1	1	1	1	1	1	1	1	11
Daunoraviciene et al. (2018)	1	1	1	1	1	1	1	0	1	1	1	10
Dehem et al. (2019)	1	1	1	1	1	1	0	1	1	1	1	10
Hesse et al. (2013)	1	1	1	1	1	1	1	1	1	1	1	11
Ranzani et al. (2020)	1	1	1	1	1	1	1	0	1	1	1	10
Sale et al. (2014)	1	1	1	1	1	1	1	0	1	1	1	10
Takahashi et al. (2016)	1	1	1	1	1	1	1	1	1	1	1	11
Takebayashi et al. (2022)	1	1	1	1	1	1	1	1	1	1	1	11

Description of the question criteria:

1 = Does the experiment clearly address the clinical problem?
2 = Was the intervention given to stroke patients randomized?
3 = Were researchers, patients and health workers blinded?
4 = Were the study groups similar at the start of the study?
5 = Apart from the allocated intervention, are the groups treated the same?
6 = Are all the samples included in the experiment taken into account? and were they analyzed in randomized groups?

7 = Was the effect of the intervention large enough?
8 = How precise is the effect of the intervention?
9 = Are the research results applicable to the local population?
10 = Is the overall outcome clinically important to consider in this article?
11 = Are the benefits of providing the intervention greater than the disadvantages and cost

Answer score description:

0 = No
1 = Yes

Table 2. Description of the primary RCT study on the effect of using assistive therapy robots on improving the functional abilities of stroke patients' hands (N=537)

Author (year)	Country	Sample	P	I	C	O
Aprile et al. (2020)	Italy	190	Subacute Stroke	RAT	Conventional Therapy	Functional Hands
Carpinela et al. (2020)	Italy	38	Strokes	RAT	Conventional Therapy	Functional Hands
Daunoraviciene et al. (2018)	Lithuania	34	Strokes	RAT	Conventional Therapy	Functional Hands
Dehem et al. (2019)	Belgium	45	Acute Stroke	RAT	Conventional Therapy	Functional Hands
Hesse et al. (2013)	German	50	Subacute Stroke	RAT	Conventional Therapy	Functional Hands
Ranzani et al. (2020)	Switzerland	27	Subacute Stroke	RAT	Conventional Therapy	Functional Hands
Sale et al. (2014)	Italy	20	Acute Stroke	RAT	Conventional Therapy	Functional Hands
Takahashi et al. (2016)	Japan	56	Subacute Stroke	RAT	Conventional Therapy	Functional Hands
Takebayashi et al. (2022)	Japan	77	Chronic Stroke	RAT	Conventional Therapy	Functional Hands

Based on Table 2, the description of the primary research on the effect of the use of assistive therapy robots on the functional abilities of the hands of stroke patients was carried out by a meta-analysis of 9 articles using a randomized controlled trial (RCT) study design with a total sample of 537, the smallest sample was 20 and the largest 190.

Table 3. Standardized Mean Difference (SMD) the effect of assistive therapy robots on improving the functional abilities of stroke patients' hands (N=537)

Author (year)	SMD	SE
Aprile *et al.* (2020)	-0.08	1.183
Carpinella *et al.* (2020)	-0.82	0.336
Daunoraviciene *et al.* (2018)	0.695	0.322
Dehem *et al.* (2019)	0.47	0.650
Hesse *et al.* (2014)	-0.25	0.284
Ranzani *et al.* (2020)	0.07	0.385
Sale *et al.* (2014)	-1.17	0.485
Takahashi *et al.* (2016)	0.55	0.273
Takebayashi *et al.* (2022)	0.15	0.228

The Forest Plot in Figure 3 shows that the results of the analysis show that there is no difference in effectiveness between the use of assistive therapy robots and conventional therapy in improving the functional abilities of stroke patients' hands (SMD = -0.02; 95% CI = -0.42 to 0.38; p= 0.930). The Forest Plot also shows significant heterogeneity of effect estimates between studies (I^2=64%; p=0.005). Thus the calculation of the average effect estimate is carried out using the Random Effect Model (REM) approach.

The funnel plot in Figure 4 shows an asymmetrical distribution of the right and left plots, indicating publication bias.

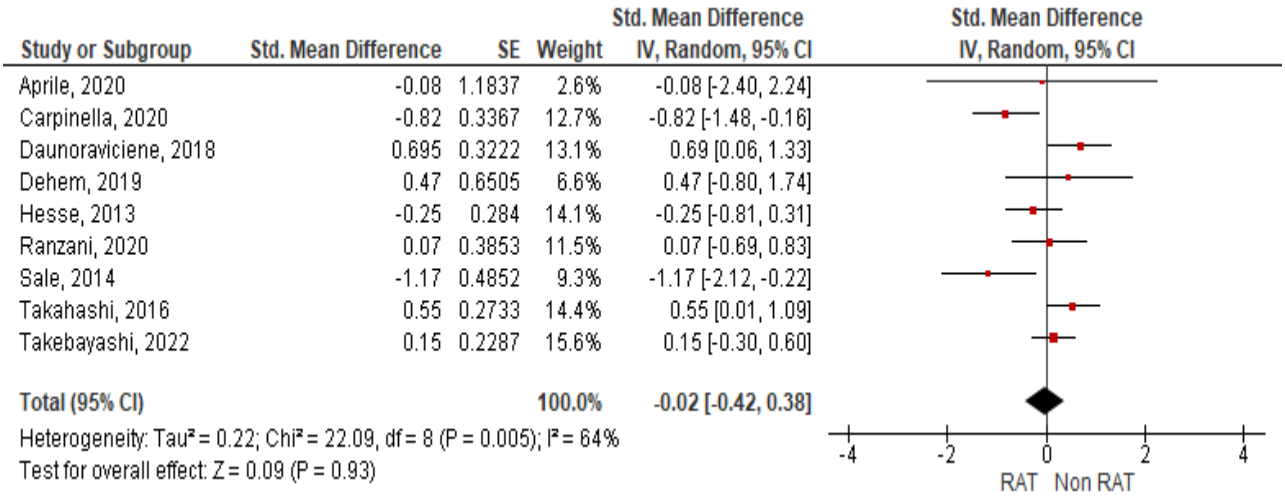

Figure 3. Forest Plot of the effect of using assistive therapy robots on the functional ability of the stroke patient's hand

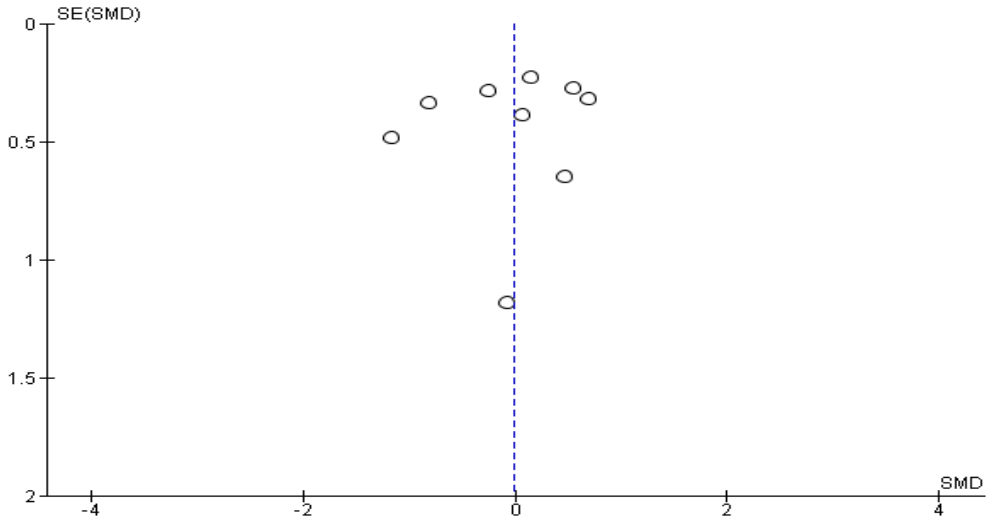

Figure 4. Funnel plot of the effect of using assistive therapy robots on the functional ability of the stroke patient's hand

DISCUSSION

Stroke is a functional disorder of the brain that occurs suddenly with clinical signs and symptoms both focal and global. It can last for more than 24 hours and can cause death due to circulatory disorders in the brain (Coupland et al., 2017). Stroke is a complicated condition with various kinds of disorders

that arise and are one of the main causes of disability for a long time and become a burden for sufferers because it can affect their quality of life (Zhang et al., 2016).

Most stroke patients experience motor disturbances on one side (Hemiparesis). It can cause unilateral or bilateral upper extremity dysfunction from the early stages of the disease and causing muscle weakness, spasticity, loss of coordination and sensory disturbances of the upper limbs (Maris et al., 2018), besides In addition, stroke also causes weakness, impairment and limitations of motor, sensory, perceptual functions (Franck et al., 2017). Robotic therapy is a promising technology for the rehabilitation of patients with motor disorders caused by stroke (Bertani et al., 2017).

Robotic therapy is a promising technology for the rehabilitation of patients with motor disorders caused by stroke (Bertani et al., 2017). Compared to conventional therapists robotic therapy requires several rehabilitation training sessions, resulting in impractical and unaffordable therapy for many patients. Robotic therapy techniques can be used for patients without maximum assistance, ensuring safe, intensive, and task-oriented rehabilitation as well as relatively measurable progress from the therapy program (Aggogeri et al., 2019).

The increasing complexity of motor problems caused by damage to the brain will affect the results obtained from the use of Robot Assistive Therapy in stroke patients. The initial phase is called the acute phase and lasts about 2 weeks after the onset of the lesion, the second phase is the subacute phase lasting up to 6 months after onset, the chronic phase begins months to years after the stroke, and can continue for the rest of the person's life (Kiran, 2012). This has an impact on the effectiveness of the use of robotic therapy.

There were 9 RCT study articles from Belgium, Italy, Germany, Lithuania, Switzerland and Japan with a total sample of 537. This meta-analysis concluded that there was no difference in effectiveness between the use of assistive therapy robots and conventional therapy in improving the functional abilities of stroke patients' hands. SMD = -0.02; 95% CI= -0.42 to 0.38; p = 0.930). The heterogeneity of effect estimates between studies is quite large (I2=64%; p=0.005) so that the calculation of the average effect estimate is carried out using the Random Effect Model (REM) approach..

The use of robotic therapy in chronic stroke patients with various disorders in limbs, coordination and perception using robotic therapy has almost the same effectiveness as conventional therapy to improve the functional abilities of stroke patients' hands (Orihuela-Espina et al., 2016). In accordance with the study of Zhang et al., (2022) which showed that RAT has a beneficial effect on motor control and functional activity of the upper extremities experiencing hemiparesis in stroke patients but there is no evidence to support its long-term effect. RAT advantage is affected by the amount of training time, training mode. To achieve the best therapeutic effect, robotic therapy should be applied with more than 15 hours of training time, the duration of therapy time affects the effectiveness of using RAT.

According to the results of research from Saragih et al., (2022) which involved 2,774 stroke patients from 52 studies, RAT has been shown to improve the quality of functional movement, reduce balance disorders, and pain is almost the same as conventional therapy. Robot-assisted therapy can be used as an alternative therapy and complement therapy. conventional method to assist post-stroke rehabilitation programs.

Robotic therapy is more efficient in use by reducing direct contact with the therapist but therapy programs can continue to be carried out with measurable results.

This study has several limitations, including language bias because the primary research was published in English and primary study searches were only conducted in 5 online databases. It is hoped that future research will be able to conduct research using a larger number of subjects and a higher duration and follow-up. In addition, primary research on the effect of using assistive therapy robots has never been carried out in Indonesia.

AUTHOR CONTRIBUTION

Haris Sutopo as the main researcher chose the topic, conducted searches for research data collection, and conducted research data analysis. Bhisma Murti and Argyo Demartoto conducted a review of research documents.

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The study was self-funded.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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