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UNLOCKING THE POTENTIAL: A SYSTEMIC REVIEW AND META-ANALYSIS OF MULTI-DISCIPLINARY REHABILITATION TECHNIQUES TO IMPROVE DEXTERITY AMONG CHRONIC STROKE PATIENTS

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ABSTRACT

Introduction:*Around 85% of stroke patients experience altered arm function. Determining the most effective rehabilitation technique remains challenging. Our research focuses on evaluating the effectiveness and limitations of commonly used techniques in hemiplegic stroke rehabilitation, particularly in Pakistan, to identify the most effective among the top four methods.*

Objectives: *To assess the effectiveness of rehabilitation techniques.*
To determine the best technique for rehabilitation.

Methods: *Data from 2015-2024 were collected from MEDLINE, PubMed, EMBASE, and other databases. We analyzed RCTs on CIMT, FES, TENS, and MT comparing statistical results based on the scales used. And risk of biasness was determined by using Cochrane risk of biasness.*

Result: *CIMT showed a large effect size (Hedges' g = 4.14) but with wide variability. FES had a moderately large effect size (Hedges' g = 0.86) with more consistent outcomes. Mirror Therapy showed moderate effect size (Hedges' g = 0.53), and TENS had significant effects but high variability. While CIMT is impactful, FES and Mirror Therapy are more reliable.*

Conclusion: *FES and MT emerged as the most reliable techniques due to consistent results and minimal publication bias, making them preferable for therapeutic use. These findings provide insights for informed decisions on treatment effectiveness.*

Keywords: *Chronic stroke, hemiplegia, hand function, dexterity*

INTRODUCTION

Background

South Asia is the home of 20% world population with higher incidence of cardiovascular and cerebrovascular accident commonly in Pakistan, India, Brazil, China and Russia (1). However, a true epidemiological data in Pakistan is not available that shows the reasons for the difference of incidence rate of stroke in Pakistan as compared to western countries (1). Stroke is one of the leading causes of disability and rank as the second leading cause of death worldwide. Accounting for 11 to 30% of age >60 have stroke in Pakistan (1). However, its rehabilitation differs substantially in different rehabilitation centers. World stroke organization makes it easy for us to determine the incidence and prevalence rate of stroke by combining all the relevant data according to the global stroke fact sheet around 47% of men and 53% of women are affected by stroke every year (2).

Stroke is also referred as cerebrovascular accident, but it does not mean it's an accidental event but it's a brain attack where sudden supply of blood to the area of brain is affected (3). 85% of stroke is ischemic caused by arteriosclerosis, cardio embolism and large artery athero thrombi embolism found to be the

common risk factors (4). While 15% of stroke is intracerebral hemorrhage, these hemorrhages can be deep and lobar (4). Deep hemorrhages are caused by hypertension while lobar hemorrhages are caused by cerebral amyloid angiopathy and atherosclerosis (4). Several impairments have been found post stroke that includes sensory and motor problem due to involvement of pyramidal tract and object handling is one of the major issues (5). Here the challenge is found in prehensile movement, object handling and cues related to the environment such as tools or assistive devices (5). Dexterity is commonly dominant in right hand and in simple terms it is the ability of hand perform skill movement with precision and accuracy (5). According to the approaches it has been found that dexterity is not limited to motor function of hand, but environment and cognition also plays a crucial role in influencing the therapeutic effects of rehabilitation intervention and affecting the therapeutic outcome (5). The importance of rehabilitation for hemiplegic stroke patients in society and medicine is also rising. While some studies use the term hemiplegia and hemiparesis interchangeably because they produce the same symptoms however hemiparesis is defined as partial paralysis in one side of body resulting in weakness of the affected side while hemiplegia defines as complete paralysis in one side of body (6). The hemiplegic stroke patient suffers from impaired motor skills such as poor gripping, pinching and holding in distal part of upper extremity, spasticity, poor balance impaired gait, visual disturbance, sensory loss such as numbness and paresthesia and difficulty in speech (6). Different types of upper extremity impairments have been found post stroke and the therapeutic intervention depends on the type and severity of impairment (7). There are three most common impairments found in post stroke 1) learned non- use 2) learned bad-use 3) forgetting how to complete the complete the task (8). Brain is divided into three parts: primary motor cortex, supplemental and premotor cortex and prefrontal cortex (9). Damage to any of these areas can lead to impaired motor function of the contralateral side (9). Each part plays different roles in initiating a movement. For instance, premotor cortex plans a movement; primary motor cortex initiates and executes a movement (9). It is also responsible for analyzing direction and force of the movement (10).

Abnormal motor synergy is found in stroke patient such as when we have to grasp an object we flex our shoulder and extend the elbow but the stroke patients uses shoulder abductors and elbow flexors to grasp the object due to decrease descending motor commands and the third impairment is forgetting its same as you learned how to ride a bicycle and due to breaks in your training you forget your learned skill similarly the breaks in rehabilitation leads to detraining among stroke patients (11). Several researches have been published that indicates various strategies and interventions (robotics, neuromuscular stimulation, orthosis, constrained induced movement therapy, biofeedback, mirror therapy or simply the manual mobilization techniques are all associated with improvement in motor function, but also experience significant limitations (11). Therefore, which technique is more effective among all of them is still a challenge for a researcher and a therapist. Our research particularly emphasis in finding the effectiveness and limitation of each technique used commonly in hemiplegic stroke patient's rehabilitation (11).

After stroke impairment in hands motor function is commonly found (12). After six months of severe stroke one third of patients develop wrist and hand contractures and more than 50% of individuals do not recover normal motor function and the neurophysiological mechanism behind the recovery is complex and depend on stage of recovery (12).

Findings from clinical trials support that constrained induced movement therapy and robotic assisted therapy is more helpful in improving hand arm dexterity to improve fine motor and gross motor skills such as pinching, grasping or manipulating an object for this we combined more than 15+ articles that helps us to identify which technique is more effective in improving hand arm dexterity and we are going to explain them one by one (12). Several impairments have been found post stroke that includes sensory and motor problem due to involvement of pyramidal tract and object handling is one of the major issues (13). Here the challenge is found in prehensile movement (precision grip and power grip), object handling and cues related to the environment such as tools or assistive devices (13). Dexterity is commonly dominant in right hand and in simple terms it is the ability of hand to perform skill movement with precision and accuracy (13).

Constrained induced movement therapy is found to be effective to improve upper extremity function in mild hemiplegia and is done by restraining the unaffected arm for more than 6 hours for 2 to 3 weeks in conjunction with repetitive training of affected arm (14). The unaffected arm is restrained by sling, mitt or glove and the recovery through CIMT is found through imaging test such as electroencephalography that shows neuroplasticity following CIMT the movement criteria decided by noting the resting position from forearm pronation and wrist flexion to actively extend metacarpophalangeal and interphalangeal joint

about 10 degrees and extend the wrist to at least 20 degrees (14). It has been found that constrained induced movement therapy doesn't benefit all individuals with hemiparesis some of them who met the inclusion criteria and all those patients who adhere constantly with the treatment sessions (14) and it is essential to meet the motor criteria to see the effectiveness of CIMT which includes 10 degree MCP and IP joint extension and 20-degree active wrist extension (14). And CIMT is not effective for moderate to severe stroke hemiparesis as compared to robotic assisted devices however they are not available easily as they are expensive but effective (15) and the efficacy of other rehabilitation techniques such as mirror therapy, virtual reality and mental practice has not been found to be effective as compared to other strategies (15).

When we compare neuromuscular electrical stimulation with TENS, we found that NMES to be more effective than TENS and combining NMES and TENS to be superior to conventional therapy with the p value<0.001(15).

In 2012 another study was conducted to see the efficacy of electromyography biofeedback as compared to conventional treatment on upper extremity function them-BF was given for 20 minutes five times a week for 3 weeks and different scales were used to see the improvement that includes Ashworth scale (AS), Brunnstrom's stage (BS) of recovery for hemiplegic arm and hand, the upper extremity function test (UEFT), the wrist and hand portion of the Fugl-Meyer scale (FMS), goniometric measurements of wrist extension, surface EMG potentials, and the Barthel Index (BI) and greater improvement found in study group (16). As science is emerging with technology, we found that we can also use robotic rehabilitation that shows promising results in improvement of upper extremity after stroke thanks to the sensors and actuators they included (16). It helps to improve muscle strength and motor function, but no effect is found in improving muscle tone (17). It uses visual and auditory feedback and use vibratory therapy to improve proprioception in fingers (17). Patients having moderate weakness, complex regional pain syndrome are also treated with conventional therapy along with mirror therapy to improve upper extremity function and some evidence shows against recommendation for routine practice of splinting as no promising results found in improving function (18).

There are many new strategies to improve motor function in stroke patients and one of them is mirror therapy. This technique is a task specific technique which employs somatosensory input to assist motor recovery as it gives visual stimulus to the patient simultaneously (18). In mirror therapy, a mirror is situated at the mid sagittal plane between the upper or lower limbs of the patient which forms the image of the non-paretic side. Movement of the non-paretic limb gives visual stimulus to the patient that he is moving his paretic limb (18). Mirror therapy not only plays a vital role in pain management but also effects sensations and visuospatial neglect (22). This technique is beneficial as it can be used in severely impaired stroke survivors (23). The phenomenon behind this technique is the activation of mirror neurons present in brain which are responsible to differentiate between right and left side. Secondly it explains the phenomenon of the brain to prioritize visual feedback over somatosensory feedback. This technique remodulates cortical mechanisms as the illusion gives response to the motor cortex that the affected limb has been moved. However, this technique is useful as it is efficient, cost effective and can be advised in home programs.

Transcutaneous electrical nerve stimulation (TENS) is a modality used in electrotherapy which is the treatment using electrical impulses. It is a battery-operated device with two or four pad electrodes which uses low voltage electrical current to block the pain pathways resulting in pain relief. The pads are placed on the surface of the skin at the site of nerve to be stimulated. This technique is used in various conditions such as fibromyalgia, osteoarthritis, tendinitis, bursitis, back pain, diabetes related neuropathy etc.

Increased incidence of stroke and lack of infrastructure and good health care in both rural and urban areas bring immediate attention in Pakistan. The incidence rate is higher as compared to the good outcomes and is due to lack of neurologist, lack of technological advancement availability and resources while treatment is cost effective in private sectors due to which patients stop their treatment session or didn't engage in rehabilitation centers which reduces their quality of life promotes limitation in societal activities. And unfortunately, no large-scale epidemiology data is available recently that provide us the accurate incidence rate of stroke in Pakistan. According to several research we found that the estimated incidence rate of stroke annually in Pakistan is 250/100,000 and due to several budget burden public sector is also not able to provide adequate resources essential for patient treatment in stroke units. Even patients who need immediate alteplase (use of thrombolytic agents to dissolve blood clots) is low due to prehospital delay.

Pakistan stroke society was established in 2001 and is affiliated with world health organization and Asia pacific organization that aims to improve quality of life of stroke patients also taken steps by conducting awareness workshops, and put emphasis on stroke units, use of thrombolytic agents, preventing reoccurrence of stroke, also targeting the neurologist, nurses and paramedical staff.

1.1 Significance of the problem

Stroke-induced hemiparesis leads to significant impairment and affecting upper extremity most patients facing difficulty in performing activities of daily living that requires fine gross motor skills such as gripping, pinching or holding patients often develop abnormal synergic patterns to compensate the movement patterns evidence (40). Different rehabilitation techniques are used as therapeutic approach worldwide and we found that CIMT, TENS, FES and mirror therapy are commonly used techniques in Pakistan but here the question arises that among all of them which technique is more effective in improving dexterity and which technique has long term benefits with less limitation. These evidence-based approaches help to bridge the gap between clinical guidelines and practices and helps the reader to identify the inconsistencies in existing research. In addition, it helps to improve patient care and emphasize on advancement in stroke research and practice.

1.2 Objective of the study

OBJECTIVE 1: Determine the worldwide incidence and prevalence rates of stroke, as well as specific figures for Pakistan.

OBJECTIVE 2: Investigate the fundamental pathophysiology underlying hemiplegia and elucidate why impaired dexterity commonly occurs in affected individuals.

OBJECTIVE 3: Compare the effectiveness of various rehabilitation techniques in enhancing dexterity among hemiplegic stroke patients, while also identifying their respective limitations.

OBJECTIVE 4: Determine the most suitable rehabilitation technique for improving dexterity among hemiplegic stroke patients in the context of Pakistan's healthcare system and socio-cultural factors.

1.3 Hypothesis

Null hypothesis (H_0): There is no significant relationship between the effectiveness of treatment techniques in stroke patients.

Alternate hypothesis (H_1): There is significant relationship between the effectiveness of treatment techniques in stroke patients. Each treatment is found to be effective at the same time

1.4 Operational Definitions

Dexterity: Ability of hand to hold or manipulate the objects (36).

CIMT: Constrained induced movement therapy is a rehabilitation approach where the sound limbs covered with mitten or glove and the patient must focus on affected limb this technique is used in post stroke survivors (37).

FES: Functional electrical stimulation uses electric charges on paralyzed or weak muscles (38).

TENS: Transcutaneous nerve stimulation uses mild electric current to treat pain and to produce muscle contraction (39).

Mirror therapy: Type of rehabilitation technique to trick the brain by creating reflective illusion to use the affected limb (18).

Review of Literature

Zheng et al in 2019 conducted a randomized controlled trial where they investigate that functional electrical stimulation (41) show more reliable results when used with the aim to improve hand arm function in hemiplegic stroke patients. For this they conducted the research on the patients admitted in neurology department of juangsu these were the patients who were diagnosed with hemiplegic stroke, aged between 20 to 80 years and brunnstrom recovery stage of iii, score of Fugl Meyer scale is less than or equal to 22 and no active wrist dorsiflexion is found while those patients who have sub Dural hematoma, tumor any trauma, unconscious, unable to follow commands, severe cognitive or communication

deficiency, implanted with pacemaker and without informed consent were excluded from the research. Patients were randomly assigned into two group one was experimental and other was control group patients were randomized based on computer-generated randomization list and allocation was concealed by numbered sealed opaque envelop both groups received 30 minutes of session for 5 times a week over 2-week period.by providing electrical stimulation the forearm extensor muscle were stimulated without patient active participation. All the patients were following up for one month after inpatient treatment 19 patients were in treatment group and 12 were in control group the experimental group show better results with mean of 66.67 and SD of 10.99 while the control group show mean of
58.25 and SD of 11.73. the major limitation of this study was of small sample size which increases risk of biasness while this can be reduced by enrollment of more patients. (41)

Huang et al in the year 2021 conducted a parallel randomized control trial to compare the effectiveness of functional electrical stimulation with the conventional therapy(42) for this fifty patients were selected on the basis of having stroke past 6 months , conscious, vitally stable, age 30 to 58 years, brunnstrom recovery stage is 1 to 4 for upper limb, unilateral lesion confirmed by CT scan and MRI, and patient were voluntary participate and signed the informed consent. While those patients who have reversible stroke, severe organ dysfunction, severe cognitive dysfunction, MMSE score less than 23, have history of mental disease and cannot cooperate in rehabilitation technique, implanted with pacemaker and can't follow-up be excluded from the study. Both groups receive daily rehabilitation of one hour for five days per week for 3 weeks. Functional electrical stimulation was used to stimulate wrist extensors the stimulating electrode were placed on the belly of extensor carpi radialis with the aim to promote wrist extension almost 20 to 25 degrees. Motor function was assessed by Fugl Meyer scale helps to evaluate tendon reflexes and upper extremity function involving shoulder, elbow, wrist and hand. Each item was rated from 0 to 2. scoring 0 means no tendon reflex, score 1 means partial stimulation and score 2 means full contraction.in finding the results for continuous variable t test was is and for categorical variables chi square was used and at the end of 3 week of treatment patients who received functional electrical stimulation show better results in arm function also there is no conflict of bias as reported by the author. (42)

Sethy et al in 2016 conducted a study where they found the effectiveness' of constrained induced movement therapy in chronic stroke patients. (43) The patients were included after taking a history by using mini mental state examination, modified Ashworth scale and to assess the improvement in upper extremity function Fugl Meyer scale was used. The participants were divided into two groups group A received constrained induced movement therapy and group B received conventional therapy both groups receive the treatment for 8-week participants of CIMT were advised to follow the instructions while also follow upper extremity movement such as shoulder flexion, reaching activities, pushing, elbow extension, shoulder protraction and retraction. therefore, the patients of group A who received CIMT with bilateral arm training show better results in Fugl Meyer scale. This study has some limitations such as small sample size, no follow up, the outcomes were measured by Fugl Meyer scale which is a 66 point that assess upper extremity dimensions at a 3-point ordinal scale that marked the changes in motor function of upper extremity. (43)

Madhoun et al in the year 2020 conducted a single blinded randomized control trial where they found the effectiveness of mirror therapy in subacute and chronic stroke patients(44)' total of 30 participants were selected these were the patients who were diagnosed with stroke between the age of 25 to 80 years, had a stroke in less than or equal to 6 month, brunnstrom stage of recovery at 1 to 3, showed a good cognitive function, score of Fugl Meyer to be found is less than 47. While patients who have aphasia, unilateral neglect, musculoskeletal disease and those who were not willing to participate were excluded from the study. The participants were randomly allocated using random generator software and all subjects received 25 treatment session, 7 days per week and each participant was assessed twice one before the intervention and one after the intervention. The size of mirror was 35x40x20cm and the mirror was placed in diagonal manner to the patient along the body level between the two limbs. The sound limb was placed anterior to the mirror and the affected limb was placed behind the mirror hence whenever the patient moves the unaffected arm it gives a perception to the patient that the affected limb is moving. The patients performed movements like elbow flexion extension, ulnar and radial deviation, flexion and extension of wrist and movements of all fingers the patient can perform all these movements manually or can also hold any object such as spongy ball, a bottle of water or duster even. The results were shown as mean and standard deviation, and an independent t test or chi square test were used to assess the result between the two groups. And all the statistical findings were in favor of mirror therapy that helps to

Improve upper extremity function in subacute and chronic stroke patients. (44)
Wen et al in 2022 conducted a randomized control trial to found the efficacy of mirror therapy as compare to conventional therapy (45) the inclusion criteria include patients who have ischemic or hemorrhagic stroke, stroke confirmed by MRI or CT scan, duration of stroke is less than or equal to 6 months, moderate to severe upper extremity dysfunction having Fugl Meyer score less than 40, age between 18 to 85 years with no cognitive impairment, no vision impairment while those patients who have severe cognitive impairment, recurrence of stroke or seizures during the study, neurological or orthopedic disease, excessive spasticity in upper arm and patient who refused to participate in the study were excluded from the study. the allocation ratio was 1: 1 and a computer-generated software was used that helps in random generation of numbers and according to it 25 subjects received mirror therapy and 25 received convention therapy. The treatment session consists of one hour of session for 6 times a week for 3 weeks. The size of mirror was 35x35cm and patient seat must be adjustable and with suitable height the sound limb was placed in front of mirror and affected limb behind the mirror and the subject was asked to move the limb in all direction which is giving a perception that the affected limb is moving. According to the results of statistical findings MT and conventional therapy both have beneficial results while MT found to be effective in chronic stroke patients. (45)
Kwong et al in 2018 evaluates the effectiveness of bilateral transcutaneous electrical nerve stimulation (Bi-TENS) with task-oriented training (TOT) for stroke-related upper limb recovery. (46) Previous research highlighted benefits of Bi-TENS+TOT for lower limbs, but its effects on upper limbs were unexplored. In this randomized controlled trial, 120 participants were divided into four groups: Bi-TENS+TOT, Uni- TENS+TOT, Placebo-TENS+TOT, and a no-treatment control. They completed 20 sessions over seven weeks, with assessments at key points. The Bi-TENS+TOT group showed significantly better improvements in motor function, maintained at three months, and faster within-group progress compared to Uni- TENS+TOT. The results indicate Bi-TENS+TOT may be an effective therapy for stroke patients needing upper limb rehabilitation (46)
Lee et al in 2018 conducted a single blinded randomized control trial to find out the effectiveness of FES among stroke patients. (47) Stroke rehabilitation primarily aims to restore upper extremity function and enhance quality of life, essential for daily activities. Functional electrical stimulation (FES) has been used in recovery efforts but combining it with virtual reality (VR) might yield better results due to VR's interactive nature (47). This study evaluates the effectiveness of integrating VR with FES (VR-FES) against cyclic FES alone, specifically in improving motor recovery and quality of life for chronic stroke patients. This pilot trial involved 48 patients with hemiplegia from a unilateral stroke occurring over three months prior. Participants were assigned to either the VR-FES group or a cyclic FES group, receiving 20 sessions over four weeks. Various primary and secondary outcomes were assessed. Results indicated that VR-FES significantly improved distal motor function (Fugl-Meyer Assessment) and showed slight gains in hand function compared to cyclic FES. Other improvements were noted, but not all were statistically significant. The study suggests that combining VR with FES may lead to better motor performance in the upper extremities post-stroke than using cyclic FES alone. This approach shows promise for enhancing rehabilitation, warranting further research with larger cohorts and extended follow-up to confirm these findings. (47)
Gurbuz et al in 2016 evaluate the effectiveness of mirror therapy in improving upper extremity function in stroke patients Mirror therapy has emerged as an innovative and effective intervention for enhancing upper extremity motor function in stroke patients (48). The concept behind mirror therapy involves the use of visual feedback to promote motor recovery, leveraging the brain's plasticity to aid rehabilitation. This randomized controlled trial examined the efficacy of mirror therapy when combined with conventional rehabilitation methods. The study included thirty-one hemiplegic patients who were randomly assigned to either a mirror therapy group or a conventional therapy group. (47) Participants engaged in four weeks of therapy, with the mirror group using a mirror for visual feedback during exercises. Both groups improved, but the mirror therapy group demonstrated significantly greater gains on the Fugl-Meyer Assessment. Integrating mirror therapy into rehabilitation enhances motor recovery, suggesting further investigation its long-term benefits is necessary. (48)
Tahir et al in 2019 conducted a randomized control trial to find the efficacy pf transcutaneous electrical nerve stimulation among chronic stroke patients as compared to conventional therapy they conducted single blinded randomized control trial on 76 individuals and have at least one year of stroke history group A having 38 participants received low frequency transcutaneous electrical nerve stimulation and group B

received conventional therapy. Both groups received intervention for 5 days per week for 45 minutes till 3 weeks. The study was conducted in tertiary care hospitals of Karachi and the duration of study is 6 months. The sampling technique used was probability sampling technique. The data was analyzed and entered in SPSS version 20. paired t test was applied for within group analysis and independent t test was used for comparison of post mean values. The results showed that both TENS and conventional therapy are equally effective but better results will be obtained if we combined TENS with conventional therapy. (49)

Chen et al in 2022 conducted a randomized controlled trial of 4 group parallel design study where they combined TENS with task oriented training (50) to evaluate its effectiveness in upper extremity of stroke patients 120 participants participated in this study and four groups were designed one with bilateral TENS combined with task oriented training, unilateral training with TENS, placebo group and the control group the duration of the session was 60 minutes For 3x a week for 7 weeks. For outcome measure fugal Meyer assessment scale was used and they were assessed at baseline then at mid intervention and then at post intervention and at 1 and 3 months of follow-up's results of the study showed that patients who received bilateral TENS improves earlier with a p value of 0.004 and these improvements were maintained at 3 months of follow-up (50)

Jung et al in 2017 conducted a randomized controlled trial where they combined TENS with task related activities to see its effectiveness on the paretic upper extremity among chronic stroke patients. (51) 46 stroke survivors participated in this study two groups were made one which received task related training combined with TENS and other was task related training combined with placebo group both groups have 23 number of participants. The duration of treatment session was 30 minutes for five times a week given for 4 weeks. The outcome measure was assessed by using Fugl Meyer scale for upper extremity and patients were assessed before and after intervention. After the treatment both groups show improvement in active range of motion and in muscle strength, but participants of task related training combined with TENS show significantly greater improvement in muscle strength and range of motion. Thus, indicating the somatosensory benefits of TENS (51)

Wei Chen et al in 2023 conducted research to find the efficacy of mirror therapy and its impact on self-efficacy among stroke patients. (52(this is a single blinded randomized controlled trial where the objective was to investigate whether mirror therapy will augment the benefits of robot assisted therapy for these 43 stroke patients participated in this study and total 18 intervention session was provided for 30 minutes. The study was working on three main domains 1) independence in daily living, 2) self-efficacy,3) motor function. The results show that both mirror therapy and robotic assisted therapy show better results however mirror therapy didn't augment the effect of robotic assisted therapy in domains of independence of living or motor function (52)

Zhang et al in 2024 conducted research to find the evidence of mirror therapy in recruiting the ipsilateral motor pathway among stroke survivors (53). a total of 35 chronic stroke patients participated in this randomized controlled trial 16 patients were given mirror therapy while nineteen were participated in conventional therapy. The treatment was given for over a period of 4 weeks and Fugl Meyer assessment scale for upper extremity was used before and after intervention.to find the brain reorganization FMRI was used, and the findings indicate that use of mirror therapy improves the ipsilateral motor pathway by increasing the neural activity. And the results found the involvement of attention network and mirror neuron in mirror therapy. This will help the patient to focus more on the affected side and bring therapeutic change among stroke survivors (53)

Methodology

Study Design

It was a systemic review and meta-analysis.

Study Population/Settings

Every aspect of this review from data searching to statistical analysis was conducted on the ground of LIAQUAT NATIONAL SCHOOL OF PHYSIOTHERAPY (LNSOP), while the RCTs included were all carried out in hospital settings

Searching strategy

Randomized control trials eligible for inclusion was sought out by searching the following available

databases: MEDLINE, PubMed, EMBASE, Cochrane, controlled trials register, Science Direct, SCOPUS, CINAHIL etc. The following electronic search terms/strategies were included: chronic stroke, constrained induced movement therapy (CIMT), Functional electrical stimulation (FES), mirror therapy and transcutaneous electrical nerve stimulation (TENS) were used. MeSH (MEDICAL SUBJECT AND HEADING) and Boolean operators were combined to improve specificity. A summary of searching strategy is listed in table 1.

PICO Format Search with Bullion Keywords (And) (OR)

DATABASES	PATEINT	INTERVENTION	COMPARISION	OUTCOME
EBSCO, PubMed, Pedro, Science Direct, Scopus, MEDLINE, CINAHL, and Web of Science	Chronic stroke Age 20 to 85 Hemiplegia OR hemiparesis	CIMT FES TENS MIRROR THERAPY	Conventional therapy that includes Range of motion exercises Proprioceptive neuromuscular facilitation OR Standard physical therapy OR Traditional physical therapy	Dexterity OR Hand arm function OR Hand arm coordination OR Fine and gross motor skills

Table 1: Searching strategy utilized in the study

Study Duration
The duration of this study was 9 months.

Inclusion Criteria
Only Randomized Controlled Trials (RCTs)were eligible
Age group of more than or equal to 18 years.
No restrictions were made regarding the gender (male or female).
We included post-stroke survivors only.
The intervention should include CIMT, FES, TENS and mirror therapy in combination with conventional physiotherapy or versus conventional physiotherapy.
Studies that used measurement scales such as Fugl-Meyer scale, Ashworth scale, WOLF scale etc.

Exclusion Criteria
Exclusion Criteria RCTs consisting of individuals having diagnoses other than stroke were excluded.
RCTs that included a severe cognitive or communication disorder (MMSE >25), limited range of motion due to limb contracture or deformity, an open wound or pressure ulcer, uncontrolled hypertension or orthostatic hypotension, the presence of a serious medical
condition such as cardiovascular disease or heart failure, a malignancy, pulmonary disease, risk of fracture due to severe osteoporosis, difficulty walking due to lower extremity musculoskeletal disease, severe psychosis, neurosis, or lack of cooperation, Modified Ashworth Scale > 3 in the lower limbs.
Written in languages other than English and studies for which full test was not available or found.

Data Collection Tools

We collected all the RCTs from the year 2015 to 2024 from the search engines of Pedro, PubMed, CINHIL, Science Direct, MEDLINE and EMBASE.

Data Collection Process

To ensure validity and accuracy of this meta-analysis the data extraction was made from similar RCTs found online from the electronic websites and databases listed above. By similarly it is meant that the sample size, baseline parameters comparison and outcomes measures or end results of all the RCTs were similar. The validity of the author was taken into consideration and the time of study selection was done from the years 2015-2024, data collection was a form of secondhand collection. Inconsistent, Irrelevant, duplicate and ambiguous data was excluded by the process of rigorous, thorough and active reading.

Evaluation of Methodological Quality and Level of Evidence

The methodological quality of the included studies was assessed by Pedro scale which consist of 10 domains. RCTS with score of 9-10 considered as high quality or excellent, score 6-8 is considered as good while score 4-5 is fair and score less than 4 is considered as poor methodological quality.

Risk of Bias Assessment

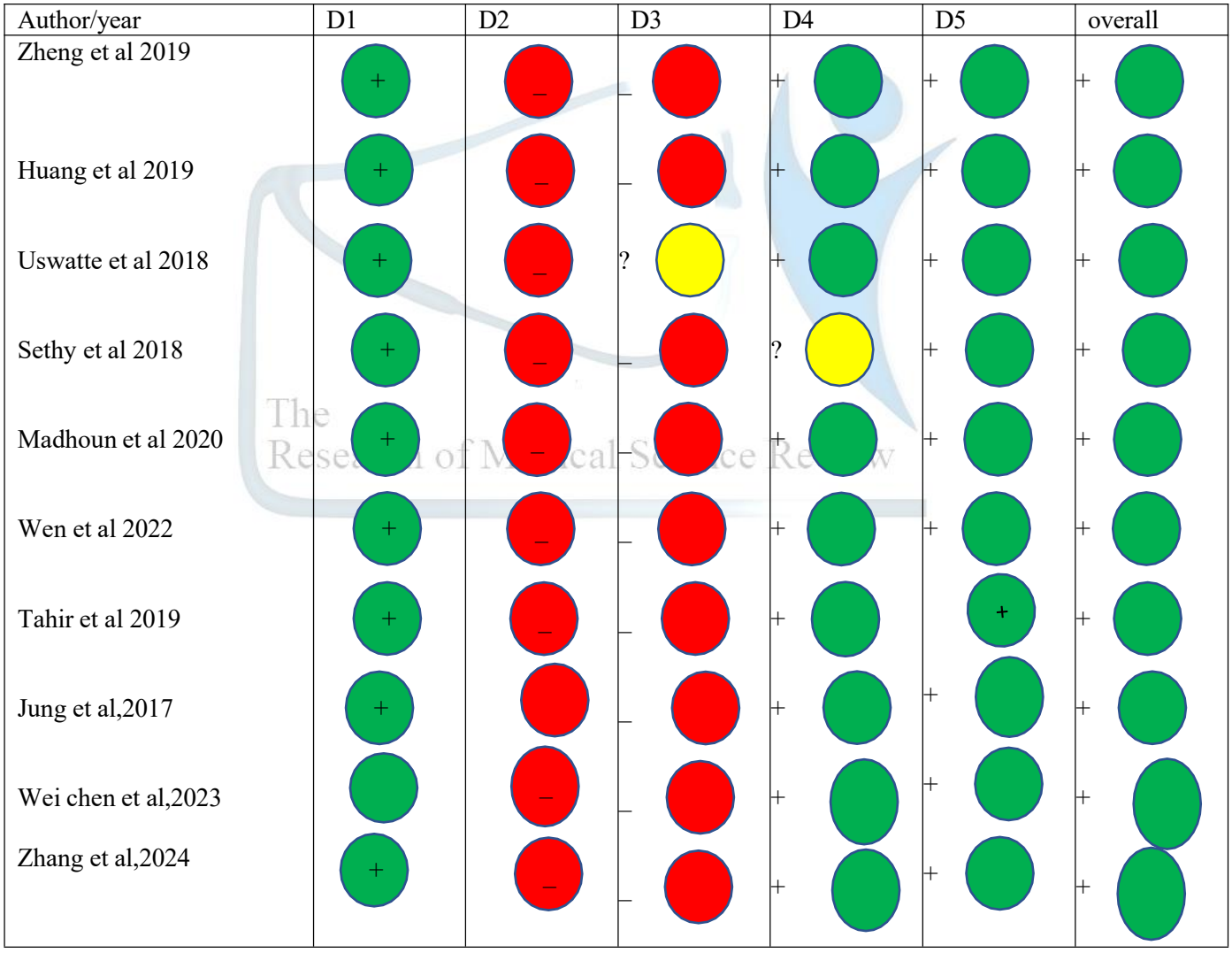
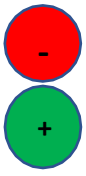


Table 2: Cochrane Risk of BiasnessDomains Legends
D1 randomization process
D2 deviation from the intended intervention
D3 missing outcome data
measurement of the outcome



high risk

some concern D4

D5 selection of the reported result ? **low risk**

1.3 Data Synthesis

205 articles were identified from PubMed and 400 were found from google scholar and Cochrane library while 90 articles were found from additional sources such as EMBASE, MEDLINE, CINAHIL and Scopus so the total articles found to be 695 however among them 340 articles found to be duplicate. The duplicate articles were removed and those articles who didn't meet the eligibility criteria were removed that includes those articles who compare the techniques with those techniques which are not practice in Pakistan, acute phase patients, full text links were not available, and studies conducted before 2015. After proper screening only 13 articles were found to be eligible for our qualitative and quantitative study.

1.4 Research timeline

- The duration of our meta-analysis was 9 months starting from 6th March 2024 to 13th November 2024
- Planning the search strategy (6 march to 14 April 2024)
- Study selection (15th April 2024)
- Synopsis proposal accepted on date (10 May 2024)
- Removing duplicates (20 September 2024)
- Statistical analysis (30 September 2024)
- Completion of writing process (13 November 2024)

1.5 Methodological Quality

Pedro score was used to critically appraise the methodological quality of research on effectiveness of CIMT on upper extremity recovery among hemiplegic stroke patients and detect several potential risks of bias. The Pedro scale uses 10 items and asses the quality of trial based on randomization procedure, concealed allocation, blinding of patients, blinding of assessors, adequate follow-up, intention-to-treat analysis, between-group comparability, between-group statistical comparison, and point estimate and variability. It ranged from 4 to 8 the outcome assessors were all blinded except 9. The outcome measures included all RCTs, systemic review, meta-analysis and control trials using Pedro score higher than or equal to 4 score less than or equal to 4 was low quality and excluded from systemic review. Score 4-7/10 is methodological moderate quality and score higher than 7 is considered methodological high-quality trial.

1.6 Ethical considerations

The RCTs that were included in this research have taken informed consent from its subjects and participation was voluntary, the reasons for the lost to follow up data or dropouts post baseline assessment were other than serious complications or death of the participants due to the interventions given. The permission and consent to use these RCTs was taken directly from the authors via E-mail. All participant data was kept private and confidential.

2 Result

2.1 Characteristics of Included Studies

Among the ten studies, 428 participants in the trial and the stroke-controlled trial involves all middle age to elderly age population range between 20 to 85 years old. All participants who participated in the trial suffered from ischemic or hemorrhagic stroke and they reported the symptoms of decreased hand arm movement usually after 6 month of post stroke that indicates that these were the patients of chronic stroke. Among the 13 studies 11 studies included participants of chronic stroke while 2 studies involved participants of subacute with the same complain of dexterity issue (41,42,43,44,45,46,47,48,49,50).

All included RCTS compared the treatment group with the placebo group or with the conventional therapy. Among them 5 studies compared their treatments with occupational therapy that includes task-based activities of functional activities while 2 studies compared their treatment with neuromuscular electrical nerve stimulation. All these treatment durations lasted for almost 3 to 4 weeks with 20 to 30 minutes of session, 5 days per week while the individual duration of each technique is summarized in the table 3.

AUTHOR	AGE	CHRONICITY	INTERVENTION	CONTROL	DURATION	OUTCOME MEASURES	INFERENCES
Zheng et al,2019	20-80 years	subacute	Functional electrical stimulation	Neuromuscular electrical nerve stimulation	20 minutes, for 5 days over 8 weeks of period	Fugyl-Meyer scale	Functional assessment was performed at baseline and after 2 weeks of intervention and to check ROM in wrist dorsiflexors
Huang et al,2021	30-85 years old	subacute	Functional electrical stimulation	Neuromuscular electrical stimulation	20 minutes of session, for 5 days over 3 weeks of period	Fugl-Meyer scale	FES show better results in improving EMG response of paretic extensor carpi radialis
Uswatte et al,2018	40-60 years	chronic	Constrained induced movement therapy	Conventional therapy	6 hours of therapy for 15 consecutive weekdays	Fugl-Meyer scale	CIMT produces much better and more persistent results when used daily for chronic upper extremity hemiparesis
Sethy et al,2018	30-75 years	chronic	Constrained induced movement therapy	Conventional therapy	1 hour per day,5 days per week for 8 weeks period	Fugl-Meyer scale	CIMT is helpful in improving upper extremity function in chronic hemiparesis
Wen et al,2022	18 to 80 years	chronic	Mirror therapy	Occupation therapy	30 minutes session for 6x a week for 3 weeks	Fugl-Meyer scale	MT can be considered as adjunctive therapy in improving activities of daily living
Madhoun et al,2020	20-85 years	chronic	Mirror therapy	Occupation therapy	25 minutes per day for 25 days	Fugl-Meyer scale	Mirror therapy is effective in improving motor function and ADLS
Tahir et al,2019	20-80 years	chronic	Transcutaneous electrical nerve stimulation	Occupational therapy	45 minutes session for 5 days per week till 3 weeks	Fugl-Meyer scale	TENS along with conventional therapy is found to be effective in improving function of upper extremity
Wei Chen et al,2023	49-70 years	chronic	Mirror therapy	conventional	60 minutes per session for 3 weeks	Fugl-Meyer scale	To improve self- efficacy of post stroke patient combination of mirror therapy with robotic assistance is found to be beneficial
Zhang et al,2019	25-70 years	chronic	Mirror therapy	Conventional therapy	1-hour session	Fugl-Meyer scale	MT is found to be effective as it recruits the neural activity
Jung et al, 2017	35-70 years	chronic	TENS	Conventional therapy	30 minutes session	Fugl-Meyer scale	Tens when combined with task-based activities show better results

Table 3: Characteristics of Included Studies

2.2 Quantitative Synthesis

Functional electrical stimulation

Zheng et al., 2019: The treatment group showed a mean score of 20.62 with a standard deviation of 6.34 , while the control group had a mean score of 22.65 with a standard deviation of 5.67. The Hedges' g value was 1.13, indicating a moderately large effect size favoring the treatment, with a weight of 10.61%.

Huang et al., 2021: The treatment group's mean score was 7.8 (SD = 7.27) compared to the control group's mean of 6.84 (SD = 8.19). Hedges' g was 0.22, suggesting a small effect size with a weight of 11.26%.

Overall for FES:
The pooled effect size (Hedges' g) was 0.86, with considerable heterogeneity (I^2 = 77.40%, H^2 = 4.43, p = 0.04), indicating that results varied across studies.

Constrained Induced Movement Therapy:
Uswatte et al., 2018: Demonstrated a substantial effect size with Hedges' g of 7.42, showing that the tre atment group (mean = 65, SD = 9) outperformed the control group (mean = 7, SD = 4), with a weight of 2 .55%.
Sethy et al., 2018: Reported a Hedges' g of 1.13, with the treatment group (mean = 42.35, SD = 5.55) per forming better than the control group (mean = 34.96, SD = 3.22). The study weight was 10.04%.

Overall for Constrained Induced Movement Therapy:
The aggregated effect size was 4.14, reflecting substantial heterogeneity (I^2 = 95.00%, H^2 = 20.00, p < 0.0 0).

Mirror Therapy:
Madhoun et al., 2020: Showed a moderate effect size with Hedges' g of 1.10, favoring the treatment group (mean = 12.06, SD = 5.84) over the control group (mean = 8.46, SD = 3.92). Weight was 9.95%.
Wen et al., 2022: Reported a Hedges' g of 0.84, indicating a small to moderate effect size, with the treatment group (mean = 10.76, SD = 7.93) outperforming the control group (mean = 4.44, SD = 4.88). Weight was 11.18%.

Overall for Mirror Therapy:
The overall effect size was 0.53, with moderate heterogeneity (I^2 = 63.24%, H^2 = 2.72, p = 0.05).

Transcutaneous electrical nerve stimulation:
Tahir et al., 2019: Revealed a Hedges' g of 1.15, showing that the treatment group (mean = 9.33, SD = 12 .82) performed better than the control group (mean = 17.88, SD = 8.28)

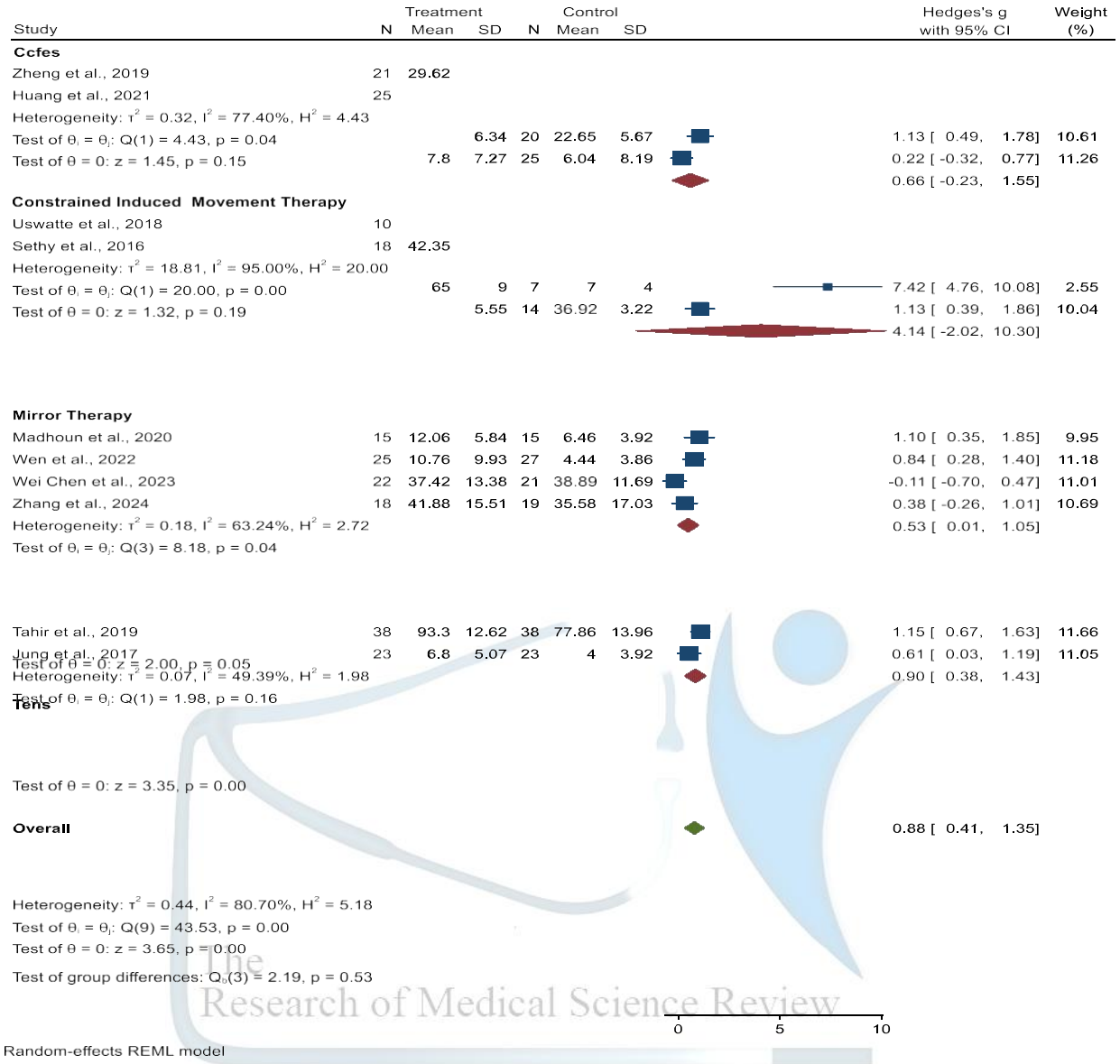


Figure 1: Forest Plot

The forest plot investigation shows constrained induced movement therapy considerable effect size among the treatment group analyzed. Regardless of high heterogenicity. Mirror therapy and functional electrical stimulation have moderate to small effect sizes with varying degree of heterogenicity and transcutaneous electrical nerve stimulation shows significant effect size as well. These results show valuable understanding into the comparative effectiveness of intervention helping in informed decision making for therapeutic intervention.

The funnel chart represents the distribution of effect sizes (Hedges' g) in contrast to their standard error for each of the four-treatment group which are functional electrical stimulation, constrained induced movement therapy, transcutaneous electrical nerve stimulation and mirror therapy.

```
Effect-size label:
      Hedges's g Effect
      size: _meta_es
        Std. err.: _meta_se

Subgroup meta-analysis summary Number of studies = 10
Random-
effects model
```

Method:
REML
Group: TREATMENTGROUP

Study	Hedges's g	[95% conf.	interval]	% weight
Group: Ccfes				
Zheng et al., 2019	1.135	0.486	1.784	10.61
Huang et al., 2021	0.224	-0.324	0.771	11.26
theta	0.662	-0.230	1.554	
Group: Constrained I~h				
Uswatte et al., 2018	7.423	4.765	10.081	2.55
Sethy et al., 2016	1.130	0.395	1.865	10.04
theta	4.141	-2.020	10.303	
Group: Mirror Therapy				
Madhoun et al., 2020	1.096	0.346	1.845	9.95
Wen et al., 2022	0.839	0.279	1.398	11.18
Wei Chen et al., 2023	-0.115	-0.702	0.473	11.01
Zhang et al., 2024	0.378	-0.259	1.015	10.69
theta	0.529	-0.011	1.047	
Group: Tens				
Tahir et al., 2019	1.149	0.667	1.630	11.66
Jung et al., 2017	0.607	0.026	1.189	11.05
theta	0.904	0.376	1.432	
Overall theta	0.880	0.407	1.353	

Figure 2: Meta-analysis Summary

Heterogeneity summary

Group	df	Q	P>Q	tau2	% I2	H2
Ccfes	1	4.43	0.035	0.321	77.40	4.43
Constrained ~h	1	20.00	0.000	18.812	95.00	20.00

Mirror Therapy	3	8.18	0.042	0.176	63.24	2.72
Tens	1	1.98	0.160	0.072	49.39	1.98
Overall	9	43.53	0.000	0.438	80.70	5.18

Test of group differences: Q_b = chi2(3) = 2.19 Prob > Q_b = 0.535

Figure 3: Heterogeneity Summary

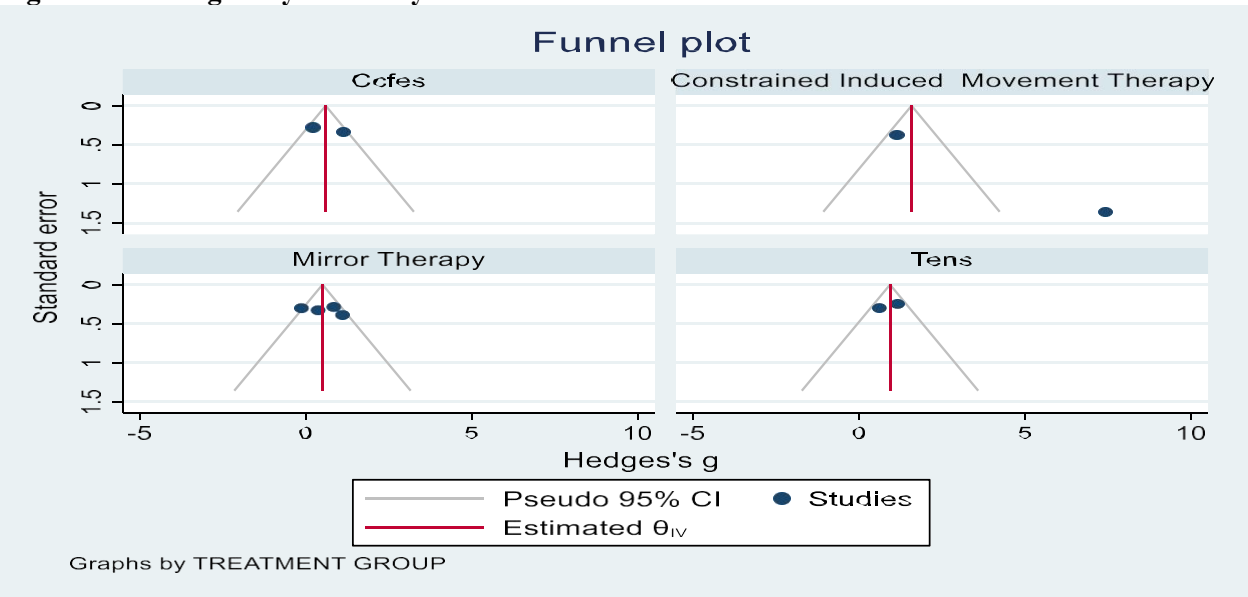


Figure 4: Funnel Chart

The blue dots of functional electrical stimulation in the funnel chart indicates that symmetrical distribution around the red vertical lines, representing minimal publication bias. The results are consistent across the studies as the funnel shape is also narrowed. Studies of constrained induced movement therapy show heterogenicity in results and the studies show wider spread. The points of mirror therapy show more symmetrical distribution which also represents minimal publication biasness also the funnel shape is narrowed that represents consistent results. The image of TENS also shows that the data points are spread out means it has high variability.

These findings suggest that functional electrical nerve stimulation and mirror therapy have more consistent results with minimal publication biasness while constrained induced movement therapy and transcutaneous electrical nerve stimulation have high variability and some significance of publication bias. These finding can help us in understanding the sturdiness and reliability of the a fore mentioned studies which were conducted for each treatment.

```
Effect-size label: Hedges's g Effect size:
        _meta_es
    Std. err.: _meta_se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 =  0; no  small-study effects
             beta1  =      6.03
SE of        beta1  =     1.288
             z      =      4.68
Prob         > |z|  =    0.0000
```

Figure 5: Regression-based Egger Test
The large effect sizes in CIMT (Hedges' g = 4.14) and the moderately large effect size in FES (Hedges' g = 0.86) indicate that these treatments have substantial impacts, though CIMT results vary widely. Mirror Therapy's moderate effect size (Hedges' g = 0.53) and FES show lower variability and more consistent outcomes, making them potentially more reliable. TENS has a significant effect but high within-study variability, suggesting inconsistent results across participants.

2.3 Methodological Quality Assessment

Among the comprised studies, one study scores 10, seven studies score 8 and one study score 7 in Pedro scale based on the assessment two study is rated as excellent and reaming 6 studies were rated as good quality. Individual study score is described in table 4-table 11.

Therapeutic Role of Additional Mirror Therapy on the Recovery of Upper Extremity Motor Function after Stroke: A Single-Blind, Randomized Controlled Trial

1. eligibility criteria were specified	no ❑	yes ☑	where: page 2 (methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 3 (study design)
3. allocation was concealed	no ☑	yes ❑	where:
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 5 (table 1)
5. there was blinding of all subjects	no ☑	yes ❑	Where:
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ❑	yes ☑	where: page 3 (study design)
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (figure 2)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ❑	yes ☑	where: (figure 2)
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑	yes ☑	Table 2
11. the study provides both point measures and measures of variability for at least one key outcome	no ❑	yes ☑	Table 2

(RESULT 8)

Table 4: PEDro Scale

Task-based mirror therapy enhances the upper limb motor function in subacute stroke patients: a randomized control trial

1. eligibility criteria were specified	no ❑	yes ☑	where: page 266 (material and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 266 (figure 1)
3. allocation was concealed	no ☑	yes ❑	where:
4. the groups were similar at baseline regarding the most important prognostic indicators	no❑	yes ☑	where: page 268 (table 1)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 266 (material and methods)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (figure 1)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑	yes ❑	where:
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑	yes ☑	where: (table 2)
11. the study provides both point measures and measures of variability for at least one key outcome	no ❑	yes ☑	where: (table 2)

Table 5: PEDro Scale

Contralaterally controlled functional electrical stimulation improves wrist dorsiflexion and upper limb function in patients with early-phase stroke: A randomized controlled trial

1. eligibility criteria were specified	no ❑	yes ☑	where: page 104 (materials and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 104 (materials and methods)
3. allocation was concealed	no ❑	yes ☑	where: page 104 (materials and methods)
4. the groups were similar at baseline regarding the most important			

prognosticindicators	no❑	yes ☑	where: page 105 (results)
5. there was blinding of all subjects	no ❑	yes ☑	Where: page 104 (materials and methods)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (figure 2)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ❑	yes ☑	where: (figure 2)
10. the results of between-group statistical comparisons are reported for at least one key outcome			no ❑ yes ☑
11. the study provides both point measures and measures of variability for at least one key outcome			no ❑ yes ☑

(RESULT 8)

Table 6: PEDro Scale

Effectiveness of contralaterally controlled functional electrical stimulation versus neuromuscular electrical stimulation on upper limb motor functional recovery in subacute stroke patients: A Randomized Controlled Trial

1. eligibility criteria were specified	no ❑	yes ☑	where: page 2 (materials and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 2 (materials and methods)
3. allocation was concealed	no ❑	yes ☑	where: page 2 (materials and methods)
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 2 materials and methods)
5. there was blinding of all subjects	no ❑	yes ☑	Where: page 2 (materials and methods)
6. there was blinding of all therapists who administered the therapy	no❑	yes ☑	where: page 2 (materials and methods)

7. there was blinding of all assessors who measured at least one key outcome	no ❑	yes ☑	where: page 3 (outcome assessme nt)
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (figure 1)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ❑	yes ☑	where: (figure 1)
10. the results of between-group statistical comparisons are reported for at least one key outcome		no ❑ yes ☑	
11. the study provides both point measures and measures of variability for at least one key outcome		no ❑ yes ☑	

(RESULT 10)

Table 7: PEDro Scale

Rehabilitation of Stroke Patients with Plegic Hands: Randomized Controlled Trial of Expanded Constraint-Induced Movement Therapy

1. eligibility criteria were specified	no ❑	yes ☑	where: page 6 (material and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 6 (figure 1)
3. allocation was concealed	no ☑	yes ❑	where: page 6(materia l and methods
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 6 (table 1)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 8 (material and methods)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:

8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups — no ❑ yes ☑ where: (page 11 of measures outcome)

9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat" — no ☑ yes ❑ where: page no 12 of measure of outcome

10. the results of between-group statistical comparisons are reported for at least one key outcome — no ❑ yes ☑ where: page no 16 of result

11. the study provides both point measures and measures of variability for at least one key outcome — no ❑ yes ☑ where: page no 17 of result

(RESULT 8)

Table 8: PEDro Scale

Effectiveness of Modified Constraint Induced Movement Therapy and Bilateral Arm Training

1. eligibility criteria were specified	no ❑	yes ☑	where: page 3(material and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 3(methodology)
3. allocation was concealed	no ☑	yes ❑	where: page 3(methodology
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 3(methodology)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 3 (methodology)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (page 4 of measures outcome)
9. all subjects for whom outcome measures were available received the			

treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑	yes ❑	where: page no 4 of measure of outcome
10. the results of between-group statistical comparisons are reported for at least one key outcome page no 5 of result	no ❑	yes ☑	where:
11. the study provides both point measures and measures of variability for at least one key outcome page no 6 of result	no ❑	yes ☑	where:

(RESULT 8)

Table 9: PEDro Scale

Efficacy Of Tens with Conventional Occupational Therapy In Improving Hand Function Of Stroke Survivors

1. eligibility criteria were specified	no ❑	yes ☑	where: page 3(materia l and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 3(method ology)
3. allocation was concealed	no ☑	yes ❑	where: page 3(method ology
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 3(method ology)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 3 (methodo logy)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (page 3 of measures outcome)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑	yes ❑	where: page no 4 of data analysis
10. the results of between-group statistical comparisons are reported for at least one key outcome 5 of discussion	no ❑	yes ☑	where: page no
11. the study provides both point measures and measures of variability for at			

least one key outcome 5 of discussion	no ❑ yes ☑	where: page no

(RESULT 8)

Table 10: PEDro Scale

The effect of sequential combination of mirror therapy and robot-assisted therapy on motor function, daily function, and self-efficacy after stroke

1. eligibility criteria were specified	no ❑	yes ☑	where: page 2(materia l and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 2method ology)
3. allocation was concealed	no ☑	yes ❑	where: page 3(method ology
4. the groups were similar at baseline regarding the most important prognosticindicators	no ❑	yes ☑	where: page 4(method ology)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 2(method ology)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (page 4 of measures outcome)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑	yes ❑	where: page no 4 of result
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑	yes ☑	where: page no 6 of discussion
11. the study provides both point measures and measures of variability for at			

least one key outcome no ❑ yes ☑where: page no 6 of discussion

(RESULT 8)

Table 11: PEDro Scale

Evidence of mirror therapy for recruitment of ipsilateral motor pathways in stroke recovery: A resting fMRI study

1. eligibility criteria were specified	no ❑	yes ☑	where: page 2(materia l and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 2method ology)
3. allocation was concealed	no ☑	yes ❑	where: page 2(method ology
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 4(method ology)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 2(method ology)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where: page no 2 of method
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where: page no 2 of method
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (page 4 of v result)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑	yes ❑	where: page no 4 of result
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑	yes ☑	where: page no 7 of discussion

11. the study provides both point measures and measures of variability for at least one key outcome	no ❑	yes ☑ where: page no 7 of discussion

(RESULT 10)

Table 12: PEDro Scale

Efficacy Of Tens with Conventional Occupational Therapy In Improving Hand Function Of Stroke Survivors

1. eligibility criteria were specified	no ❑	yes ☑	where: page 3(materia l and methods)
2. subjects were randomly allocated to groups (in a crossover study, subjectswere randomly allocated an order in which treatments were received)	no ❑	yes ☑	where: page 3(method ology)
3. allocation was concealed	no ☑	yes ❑	where: page 3(method ology
4. the groups were similar at baseline regarding the most important prognosticindicators	no❑	yes ☑	where: page 3(method ology)
5. there was blinding of all subjects	no ❑	yes ☑	Where: Page 3 (methodo logy)
6. there was blinding of all therapists who administered the therapy	no ☑	yes ❑	where:
7. there was blinding of all assessors who measured at least one key outcome	no ☑	yes ❑	where:
8. measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	no ❑	yes ☑	where: (page 3 of measures outcome)
9. all subjects for whom outcome measures were available received the			

treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	no ☑ yes ❑	where: page no 4 of data analysis

10. the results of between-group statistical comparisons are reported for at least one key outcome no ❑ yes ☑ where: page no 5 of discussion

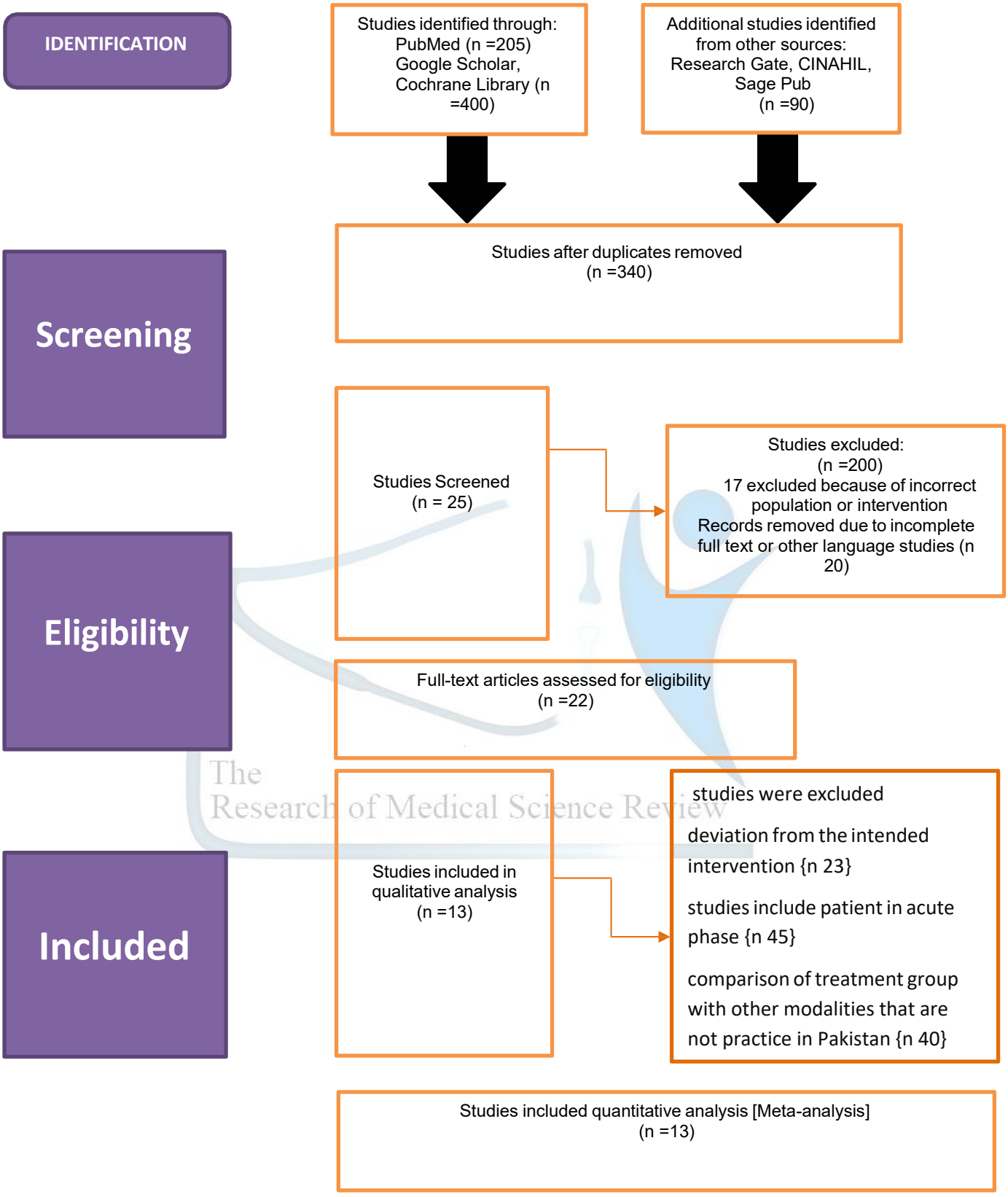
11. the study provides both point measures and measures of variability for at least one key outcome no ❑ yes ☑ where: page no 5 of discussion

(RESULT 8)

Table 13: PEDro Scale

2.4 Prisma Flow Chart

Identification of studies via databases and registers



3 Discussion

3.1 Comparison with Existing Research

This research aims to evaluate the effectiveness of four commonly used physiotherapy techniques: functional electrical stimulation (FES), transcutaneous nerve stimulation (TENS), constrained-induced

movement therapy (CIMT), and mirror therapy, in improving dexterity among chronic stroke patients. By analyzing over 40 research articles, this study compares the efficacy of these techniques using the Fugl-Meyer Assessment Scale. (54)

The primary goal is to determine which technique yields the most significant and rapid improvement in dexterity. While all four techniques have demonstrated positive outcomes compared to a control group, the question remains whether one technique is superior to others. (54) This research provides a comprehensive overview, making it easier for students and researchers to access and compare these techniques, ultimately contributing to evidence-based clinical practice. Zheng et al 2019 research finding reports that functional electrical stimulation helps in improving task oriented functional hand related activities of paretic side by signaling the neural pathway repetitively and strengthen the strength of extensor carpi muscle which helps to perform activities of daily living and patient general health.(41) Later, the effectiveness of FES has again proven by the research of Huang et al conducted in the year 2021 found that FES combines bilateral symmetrical motor training and effectively activate primary motor cortex and builds new task related neural pathways at 3 months poststroke or chronic phase, intracortical disinhibition may play a part in restructuring of cortical network and improvement of dexterity. Also, FES show improvement in hand function but not therapeutic benefits after 3 months of post stroke however it increases the response of extensor carpi radialis but not the decrease overall ratio of co contraction of flexor carpi radialis. Statistical findings of both these research shows considerable heterogenicity indicating that results varied across various studies. Studying other technique, we found that the research conducted by Uswatte et al., 2018 show that constrained induced movement therapy shows 250 percent gain in paretic arm function after construing the arm with little decrease at one year follow up and show greater improvement in performing activities of daily living such as reaching, pulling, pushing or gross motor activities. These findings are also supported by another research conducted by Sethy et al in 2016 that tell us that practicing the arm in skilled function improves recovery much faster as it focuses on motor retraining and neuromodulation which is achieved by CIMT. The aggregated effect size of both these articles were 4.14 reflecting substantial heterogenicity.

Mirror therapy which is our next selected techniques gives visual illusion to patient through visual feedback that patient affected arm is moving by targeting the premotor area which has a role in motor function of patient.(52,53) This is evident by research of Madhoun et al in 2020 where they found that mirror therapy activates the right superior occipital gyrus and superior temporal gyrus and enhances primary motor area function that further improves and activate mirror neurons that are found in frontotemporal area, superior temporal gyrus,10 and sensorimotor cortex helps to improve activities of daily living. We further confirm effectiveness of this technique by studying another research conducted by Wen et al., 2022 who's statistical results show that MT show better results as compared to conventional therapy

small to moderate effect size, with the treatment group (mean = 10.76, SD = 7.93) outperforming the control group (mean = 4.44, SD = 4.88). Weight was 11.18%. The overall analysis of both these research on MT show moderate heterogeneity ($I^2 = 63.24\%$, $H^2 = 2.72$, $p = 0.05$). The last technique transcutaneous electrical nerve stimulation effectiveness was confirmed by research conducted in the year 2019 found that application of low frequency TENS has an impact on the kinematics of motor function of upper extremity due to change in ipsilateral cortical oscillation. (52,53)

The limitations of this study include a relatively small sample size, a lack of a control group, and the subjective nature of clinical rating scales. Additionally, the short duration of the intervention and the absence of longer follow-up assessments limit the ability to assess the long-term effects of the treatment. The study also did not control for potential confounding factors such as age, stroke type, and baseline severity, which may have influenced the results. Finally, the lack of objective measures of brain plasticity, such as functional MRI, limits our understanding of the underlying mechanisms of recovery.

3.2 Strength of the Study

This research provides a comprehensive review of different articles that focuses on four major techniques namely FES, TENS, CIMT and MT that helps the students, clinicians, teachers and authors a valuable insight by comparing the techniques with the conventional therapy to see the significant outcome that helps to contribute further to evidence based clinical practice. Also now making it easier for the students to study the major four common techniques in one research article instead of visiting hundreds of websites

and then screening out which technique is effective. This will help them to save their time and making their research journey easier and we selected those techniques which are not only applicable worldwide but also practice in Pakistan as well and these all are evidence-based practice (51).

3.3 Weakness of the Study

The RCTS included have small sample size that reduces the statistical power and reducing generalizability of the findings and lack of long follow up reduces the ability to check the long-term effects of the intervention. (46)

4 Conclusion and Recommendations

Based on the analysis it has been found that among the four treatment techniques constrained induced movement therapy with high heterogenicity demonstrate substantial effect size indicating varied outcomes among various studies while functional electrical stimulation and mirror therapy show moderate to small effect size. Functional electrical stimulation shows more consistent results with minimal publication bias also transcutaneous electrical nerve stimulation exhibit moderate heterogenicity with significant effect size. Here the findings demonstrate that both functional electrical stimulation and mirror therapy were identified as the most reliable technique due to their consistent results and minimal publication bias, making them desirable for therapeutic use. These findings provide valuable visions to guide informed decisions regarding the effectiveness and strength of each treatment option.

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Appendix-I (PRISMA CHECKLIST)

TITLE: Unlocking the potential: A systemic review and meta-analysis of multidisciplinary rehabilitation techniques to improve dexterity among chronic stroke patients			
Title	1	Identify the report as a systematic review. And meta analysis	Page no 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page no 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page no 1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page no 6
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page no 16
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page no 15
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page no 19
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved,whether they worked independently, and if applicable, details of automation tools used in the process.	Page no 19
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	page no 19
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points,analyses), and if not, the methods used to decide which results to collect.	Page no 20
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page no 20

Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page no 26
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page no 27
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page no 21
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page no 21
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page no 24
	13d	Describe any methods used to synthesize results and provide a rationale for	Page no
		the choice(s If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	26
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page no 26
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page no 26
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page no 17
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page no 22
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page no 37
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page no 37
Study characteristics	17	Cite each included study and present its characteristics.	Page no 21
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page no 17
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval),deally using structured tables or plots.	Page no 22
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page no 18

	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page no 23
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page no 26
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page no 22
	23b	Discuss any limitations of the evidence included in the review.	Page no 39
	23c	Discuss any limitations of the review processes used.	Page no 39
	23d	Discuss implications of the results for practice, policy, and future research.	Page no 39
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/

Appendix-ll (Fugl Meyer scale)

Fugl-Meyer Assessment

Name: Willard Warner Date: April 19, 2023

Evaluator's Name: Dr. Andrea Safer Evaluator's Signature: Andrea Safer

Fugl-Meyer Assessment Upper Extremity (FMA-UE)

A. Upper Extremity

I. Reflex Activity

	None = 0	Can be elicited = 2
Flexors: Biceps and Fingers	☐ None	☑ Can be elicited
Extensors: Triceps	☐ None	☑ Can be elicited

Subtotal I: (4 / 4)

II. Volitional Movement Within Dynamic Flexor/Extensor Synergies (w/o gravitational help)

Flexor Synergy: Hand from contralateral knee to ipsilateral ear.
Extensor Synergy: Hand from ipsilateral ear to contralateral knee.

		None = 0	Partial = 1	Full = 2
Flexor Energy	**Shoulder** • Retraction • Elevation • Abduction (90°) • External rotation	☐ None ☐ None ☐ None ☐ None	☐ Partial ☐ Partial ☐ Partial ☐ Partial	☑ Full ☑ Full ☑ Full ☑ Full
	Elbow • Flexion	☐ None	☐ Partial	☑ Full
	Forearm • Supination	☐ None	☐ Partial	☑ Full
Extensor Synergy	**Shoulder** • Adduction/Internal Rotation	☐ None	☐ Partial	☑ Full
	Elbow • Extension	☐ None	☐ Partial	☑ Full
	Forearm • Pronation	☐ None	☐ Partial	☑ Full

Subtotal II: (18 / 18)

Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S: The post-stroke hemiplegic patient. A method for evaluation of physical performance. Scand J Rehabil Med 1975, 7:13-31. Rehabilitation Medicine, University of Gothenburg

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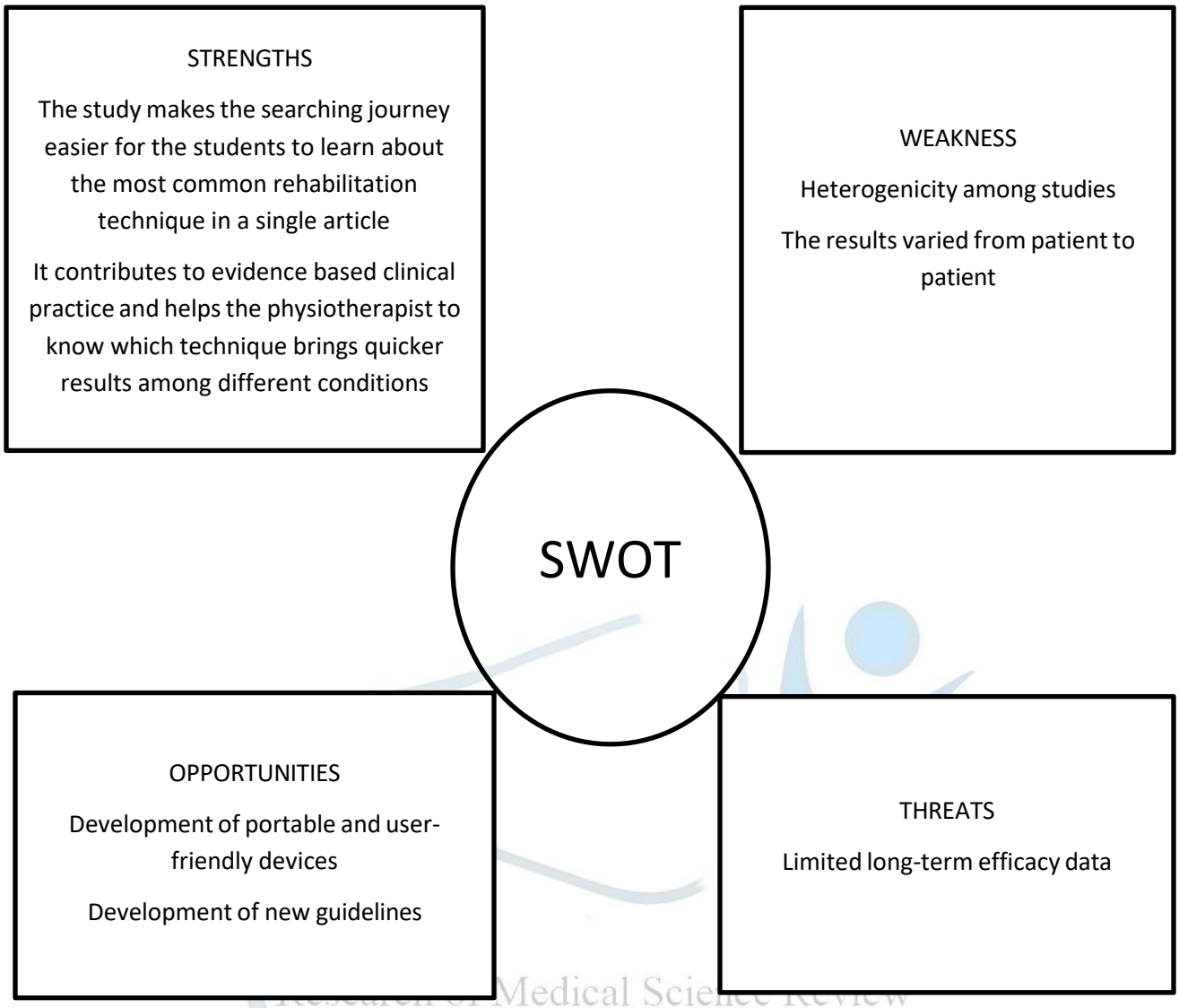

Appendix-III (SWOT analysis)