EBRSR

Chapter 10

UPPER EXTREMITY MOTOR REHABILITATION INTERVENTIONS

HEART & STROKE FOUNDATION
Canadian Partnership for Stroke Recovery

Jerome Iruthayarajah, MSc
Magdalena Mirkowski, MSc MScOT OT Reg. (Ont.)
Norine Foley, MSc
Alice Iliescu, BSc
Sarah Caughlin, PhD
Niko Fragis, BSc Candidate
Roha Alam, BHSc Candidate
Joceyln Harris, PhD OT
Sean Dukelow, MD
John Chae, MD
Jayme Knutson, PhD
Tom Miller, MD
Robert Teasell, MD

Chapter 10: Upper Extremity Motor Rehabilitation Interventions Table of contents

Key points

Bobath concept approaches and motor relearning programmes may not be beneficial for upper limb rehabilitation following stroke.

Brunnstrom movement therapy may be more beneficial than motor relearning programmes for upper limb function.

The literature is mixed regarding bilateral arm training for upper limb rehabilitation following stroke.

Bilateral arm training may not be beneficial compared to unilateral training for upper limb function.

Bilateral arm training in combination with other therapy approaches may not be beneficial for upper limb rehabilitation.

The literature is mixed regarding strength training and functional strength training for upper limb rehabilitation following stroke.

The literature is mixed regarding strength training and functional strength training for upper limb rehabilitation following stroke.

Task-specific training, alone or in combination with other therapy approaches, may be beneficial for some aspects of upper limb function following stroke.

Higher and lower intensity task-specific training may have similar effects on upper limb function.

Constraint-induced movement therapy may be beneficial for upper limb rehabilitation in the chronic phase following stroke.

The literature is mixed regarding constraint-induced movement therapy for upper limb rehabilitation in the subacute/acute phase following stroke.

Modified constraint-induced movement therapy may be beneficial for upper limb rehabilitation in the chronic phase following stroke.

Modified constraint-induced movement therapy may not be beneficial for upper limb rehabilitation in the subacute/acute phase following stroke.

Higher and lower intensity constraint-induced movement therapy may have similar effects on upper limb function in the chronic phase following stroke.

The literature is mixed regarding constraint-induced movement therapy in combination with other therapy approaches for upper limb rehabilitation following stoke.

Trunk restraint with reaching training or distributed constraint induced therapy may improve some aspects of upper limb function following stroke, but the effect of combining trunk restraint with constraint-induced movement therapy is less clear.

Stretching programs may improve some aspects of upper limb function following stroke.

Orthotics may not be beneficial for upper limb rehabilitation following stroke.

Mirror therapy on its own or in combination with other interventions can improve many aspects of upper limb function following stroke.

Mental practice, alone or in combination with constraint-induced movement therapy, may be beneficial for upper limb rehabilitation following stroke.

Mental practice in combination with virtual reality training may not be beneficial for upper limb function.

Action observation may be beneficial for some aspects of upper limb function following stroke.

The literature is mixed regarding music therapy for upper limb rehabilitation following stroke.

The literature is mixed regarding telerehabilitation for upper limb rehabilitation following stroke.

The evidence is mixed regarding arm/shoulder end-effector robotics, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

The evidence is mixed regarding arm/shoulder exoskeleton, hand exoskeleton, and hand end-effector robotics for upper limb rehabilitation.

Virtual therapy alone may not be more beneficial than conventional therapy for upper limb rehabilitation following stroke, however it may be beneficial for certain aspects of upper limb function when used in combination with conventional or other therapy approaches.

The literature is mixed regarding brain-computer interface technology for upper limb motor rehabilitation following stroke, either on its own or combined with other therapies, but it may not be beneficial alone for other aspects of upper limb function.

The literature is mixed regarding EMG biofeedback alone for upper limb rehabilitation following stroke, however it may not be beneficial when combined with other therapy approaches.

The literature is mixed regrading cyclic and EMG-triggered neuromuscular electrical stimulation types, as well as functional electrical stimulation, alone or combined with other therapy approaches, for upper limb rehabilitation following stroke.

The various types of neuromuscular electrical stimulation may not be more beneficial compared to one another.

Transcutaneous electrical nerve stimulation may be beneficial for some aspects of upper limb function following stroke.

Noxious thermal stimulation may not be beneficial for upper limb rehabilitation following stroke, whereas innocuous thermal stimulation may improve some aspects of upper limb function.

Muscle vibration may be beneficial for improving upper limb function following stroke.

The literature is mixed regarding additional afferent and peripheral stimulation for upper limb rehabilitation following stroke.

The literature is mixed regarding invasive cortical and nerve stimulation for upper limb rehabilitation following stroke.

The literature is mixed regarding low frequency repetitive transcranial magnetic stimulation, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

High frequency repetitive transcranial magnetic stimulation, alone or in combination with other therapy approaches, may be beneficial for upper limb rehabilitation.

The literature is mixed regarding bilateral repetitive transcranial magnetic stimulation for upper limb rehabilitation.

Theta burst stimulation alone may not be beneficial for upper limb function following stroke, however it may be beneficial for certain aspects of upper limb function when used in combination with repetitive transcranial magnetic stimulation.

The literature is mixed regarding anodal, cathodal, or dual transcranial direct current stimulation, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

Botulinum A likely improves spasticity in the upper limb following stroke, but not range of motion or activities of daily living. The effect on general upper limb motor function is conflicting and less clear.

Botulinum toxin A in combination with other types of therapeutic approaches may be beneficial for certain aspects of upper limb function.

Botulinum toxin B has been less well studied to date in comparison to botulinum toxin A.

Steroid injections may not be beneficial for upper limb rehabilitation following stroke.

Cerebrolysin may be beneficial for aspects of upper limb function following stroke.

The evidence is mixed regarding Levodopa for upper limb rehabilitation following stroke.

The evidence is mixed regarding atorvastatin for upper limb rehabilitation following stroke.

Antidepressants may be beneficial for aspects of upper limb function following stroke.

Dexamphetamine or methylphenidate may be beneficial for aspects of upper limb function following stroke.

Methylphenidate combined with dual transcranial direct current stimulation may be beneficial for upper limb rehabilitation following stroke.

The evidence is mixed regarding acupuncture alone for upper limb rehabilitation following

stroke. Acupuncture combined with conventional or other therapy approaches may not be beneficial for upper limb function. Some forms of acupuncture may be more beneficial than others.

Electroacupuncture with neuronavigation-assisted aspiration may be beneficial for upper limb rehabilitation following stroke, however the evidence is mixed regarding electroacupuncture and transcutaneous electrical acupoint stimulation.

Both meridian acupressure and massage therapy may be beneficial for some aspects of upper limb function following stroke.

Modified Sackett Scale

Level of evidence	Study design	Description
Level 1a	Randomized controlled trial (RCT)	More than 1 higher quality RCT (PEDro score ≥6).
Level 1b	RCT	1 higher quality RCT (PEDro score ≥6).
Level 2	RCT	Lower quality RCT (PEDro score <6).
	Prospective controlled trial (PCT)	PCT (not randomized).
	Cohort	Prospective longitudinal study using at least 2 similar groups with one exposed to a particular condition.
Level 3	Case Control	A retrospective study comparing conditions, including historical cohorts.
Level 4	Pre-Post	A prospective trial with a baseline measure, intervention, and a post-test using a single group of subjects.
	Post-test	A prospective post-test with two or more groups (intervention followed by post-test and no re-test or baseline measurement) using a single group of subjects
	Case Series	A retrospective study usually collecting variables from a chart review.
Level 5	Observational	Study using cross-sectional analysis to interpret relations. Expert opinion without explicit critical appraisal, or based on physiology, biomechanics or "first principles".
	Case Report	Pre-post or case series involving one subject.

New to the 19th edition of the Evidence-based Review of Stroke Rehabilitation

1) PICO conclusion statements

This edition of Chapter 10: Upper extremity motor rehabilitation interventions synthesizes study results from only randomized controlled trials (RCTs), all levels of evidence (LoE) and conclusion statements are now presented in the Population Intervention Comparator Outcome (PICO) format.

For example:

Population: Stroke survivors

Intervention **Comparator**

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Bilateral arm training** may not have a difference in efficacy when compared to **TENS** for improving spasticity.	1	Stinear et al. 2014

Outcome

New to these statements is also the use of colours where the levels of evidence are written.

Red statements like above, indicate that the majority of study results when grouped together show no significant differences between intervention and comparator groups.

Green statements indicate that the majority of study results when grouped together show a significant between group difference in favour of the intervention group.

For example:

Population: Stroke survivors

Intervention

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Bilateral arm training** may produce greater improvements in motor function than **conventional therapy**.	4	Meng et al. 2018; Lee et al. 2017; Stinear et al. 2008; Desrosiers et al. 2005

Outcome **Comparator**

Yellow statements indicate that the study results when grouped together are mixed or conflicting, some studies show benefit in favour of the intervention group, while others show no difference between groups.

For example:

Population: Stroke survivors

Outcome **Intervention**

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **CIMT** to improve dexterity when compared to **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	4	Shah et al. 2016; Yoon et al. 2014; Boake et al. 2007; Ro et al. 2006

Comparator

2) Upper extremity rehabilitation outcome measures

For the studies reviewed, upper extremity rehabilitation outcome measures were classified into the following broad categories to allow for synthesis of results and formulation of PICO conclusion statements:

Motor function: These outcome measures covered gross motor movements and a series of general impairment measures when using the upper extremities.

Dexterity: These outcome measures assessed fine motor and manual skills through a variety of tasks, particularly with the use of a stroke survivor's hand.

Activities of daily living: These outcome measures assessed performance and level of independence in various everyday tasks.

Spasticity: These outcome measures assessed changes in muscle tone, stiffness, and contractures.

Range of motion: These outcome measures assessed a patient's ability to freely move their upper extremity through flexion, abduction, and subluxation movements for instance, both passively and actively.

Proprioception: These outcome measures assessed sensory awareness about one's body and the location of limbs.

Stroke severity: These outcome measures assessed the severity of one's stroke through a global assessment of a multitude of deficits a stroke survivor may experience.

Muscle strength: These outcome measures assessed muscle power and strength during movements and tasks.

Outcome measures that fit these categories are described in the next few pages.

Outcome measures definitions

Motor Function

Action Research Arm Test (ARAT): Is a measure of activity limitation in the paretic arm that assesses a patient's ability to handle objects differing in size, weight and shape. The test evaluates 19 tests of arm motor function, both distally and proximally. Each test is given an ordinal score of 0, 1, 2, or 3, with higher values indicating better arm motor status. The total ARAT score is the sum of the 19 tests, and thus the maximum score is 57. This measure has been shown to have good test-retest reliability and internal validity when used to assess motor function in chronic stroke patients (Ward et al. 2019; Nomikos et al. 2018)

Brunnstrom Recovery Stages (BRS): Is a measure of motor function and muscle spasticity in stroke survivors. The measure contains 35 functional movements which are done with the guidance of a clinician (e.g. should abduction, shoulder adduction, leg flexion/extension). These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 6-point scale (1=Flaccidity is present, and no movements of the limbs can be initiated, 2=Movement occurs haltingly and spasticity begins to develop, 3=Movement is almost impossible and spasticity is severe, 4=Movement starts to be regained and spasticity begins to decline, 5=More difficult movement combinations are possible as spasticity declines further. 6=Spasticity disappears, and individual joint movements become possible). This measure has been shown to have good reliability and concurrent validity (Naghdi et al. 2010; Safaz et al. 2009).

Disabilities of the Arm, Shoulder and Hand (QuickDASH): Is a shortened version of DASH – a patient-reported outcome measure intended for upper extremity disorders. It consists of 11 items from the original 30-item DASH questionnaire, where each item has 5 response options, with scaled scores ranging from 0 (no disability) to 100 (most severe disability). The measure is shown to be valid and reliable in populations with upper extremity disorders (Gummesson et al. 2006; Salaffi et al. 2018).

Fugl-Meyer Assessment (FMA): Is an impairment measure used to assess locomotor function and control of the upper and lower extremities, including balance, sensation, and joint pain in patients poststroke. It consists of 155 items, with each item rated on a three-point ordinal scale. The maximum motor performance score is 66 points for the upper extremity section, 34 points for the lower extremity section, 14 points for the balance section, 24 points for sensation section, and 44 points each for passive joint motion and joint pain section, for a maximum of 266 points that can be attained. The upper extremity section consists of four categories (Shoulder/Elbow/Forearm, Wrist, Hand/Finger, and Coordination) and includes 23 different movements which evaluate 33 items. The items are scored on a 3-point rating scale: 0=unable to perform, 1=partial ability to perform and 2=near normal ability to perform. The measure is shown to have

good reliability and construct validity (Okuyama et al. 2018; Villian-Villian et al. 2018; Nillson et al. 2001; Sanford et al. 1993).

Finger Oscillation Test (FOT): Measures motor control and speed and is used to help detect brain damage through motor dysfunction by assessing the speed of finger movement. It measures the maximal tapping speed of the index finger of each hand by requiring the patient to work the lever arm of a mechanical counter up and down as fast as he or she can. The average number of taps in a 10-second interval is determined, and the patient performs five trials. The measure is considered a reliable indicator of brain function (Prigatano et al. 2004; Eng et al. 2013).

Jebsen-Taylor Hand Function Test (JTHFT): Is a measure used to evaluate fine motor skills with weighted and non-weighted hand functions. The test is derived from hand functions required for activities of daily living and is scored as the time taken (in seconds) to complete each subtest, with a maximum of 120 seconds permitted for each subtest. The test is shown to have good test-retest reliability (Allgower et al. 2017; Stern 1992)

Manual Function Test (MFT): Is an upper-limb function assessment measure used for evaluating proximal arm movements as well as fine and gross dexterity of hemiparetic patients after stroke. The test includes 8 subtests including forward and lateral elevation of arm, grasping, pinching, and pegboard manipulations, and ratings can range from 0 (severely impaired) to 32 (full function). The measure has been shown to have good reliability and validity (Miyamoto et al. 2009; Michimata et al. 2008).

Motor Club Assessment (MCA): Is a measure of functional movement that indicates balance and movement by assessing the range of active movement for shoulder shrugging, arm lifting, forearm supination, wrist cocking, and finger extension. Each movement is rated on a 3-point scale (where 0 = no movement, and 2 = full range of movement). (Sunderland et al. 1989)

Motor Evaluation Scale for Upper Extremity in Stroke Patients (MES-UE): Is a measure that assesses the quality of arm movement performance of the hemiparetic arm and hand in stroke patients. The scale encompasses 10 arm function items with six response categories (scores 0-5), nine hand function items with three response categories (scores 0-2), and three functional tasks with three response categories (scores 0-2). The measure is shown to be valid and reliable for measuring quality of arm movement in stroke patients (Van de Winckel et al. 2006).

Motor Status Scale (MSS): Is a measure of upper limb impairment and disability following stroke. It is divided into 4 sections and assesses shoulder, elbow/forearm, wrist and hand movements on a 6-point scale (maximum score = 82 points). This clinical scale is thought to provide a more complete measurement of upper-limb motor function than the FMA, as it evaluates the complete range of motor function of the upper limb by employing a finer grading of isolated movements. The scale has been shown to have good validity and reliability (Ferraro et al. 2002; Wei et al. 2011).

Rancho Los Amigos Functional Test for the Hemiparetic Upper Extremity (RLAFT-UE): Is a measure used to quantify functional movement ability of the hemiparetic arm in stroke patients. The test consists of a series 17 timed activities of daily living that focus on completion of everyday tasks involving the impaired limb (e.g., zipping a jacket, placing a pillow in a pillowcase). The tasks are arranged in seven levels by degree of difficulty ranging from simple single joint movements at the shoulder to complex multi-joint movements involving the hand and arm. The test has been shown to have high inter- and intra-rater reliability (Kahn et al. 2006; Wilson et al. 1984).

Rivermead Motor Assessment (RMA): Is a multi-faced measure that assesses gross motor function, leg and trunk movements and arm movements in post-stroke patients. The arm movements section consists of 15 items ranging from specific isolated movements (e.g. protracting shoulder girdle in supine position) to complex tasks (e.g. placing a string around the head and tying a bow at the back). Patients perform all movements actively, and dichotomous scores indicate either success (score 1) or failure (score 0). The measure is shown to have good test-retest reliability, content validity, and construct validity (Dong et al. 2018, Van de Winckel et al. 2007).

Sodring Motor Evaluation Scale (SMES): Is a measure of motor function and activities in patients with stroke. It is comprised of 3 subscales that evaluate the motor function of the upper and lower limb, and gross motor function. The first 2 subscales assess simple voluntary movements, while the third evaluates functional tasks including trunk movements, balance, and gait. The scale is comprised of 32 different items scored using a 5-point scale. The measure is shown to have good concurrent and construct validity, as well as good inter-rater reliability (Gor-Garcia_Fogeda et al. 2014).

Stroke Impairment Assessment Set (SIAS): Is a measure of overall motor function and visuospatial ability in stroke survivors. The measure consists of 20 functional tasks (e.g. walking, combing hair, bending, tying shoes). These tasks are then subdivided into 2 areas: tasks specific for the lower extremity and tasks specific for the upper extremity. Each task is then scored on a 6-point scale (0=cannot complete task, 5=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Panarese et al. 2016; Seki et al. 2014).

Stroke Rehabilitation Assessment of Movement (STREAM): Is a measure of overall gross motor function in stroke survivors. The measure consists of 30 functional tasks (e.g. filling up and drinking from a cup, walking, getting into and out of the bathtub, buttoning a shirt). These tasks are then subdivided into 3 areas: upper limb, lower limb and basic mobility. Each task is then scored on a 3-point scale (0=cannot complete task, 2=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Mateen et al. 2018).

Sollerman Hand Function Test (SHFT): Is a measure of general hand function and dexterity in stroke survivors. The measure consists of 20 functional tasks (e.g. stirring liquid, tying shoes, drinking from a cup, opening/shutting doors). Each task is then

scored on a 6-point scale (0=cannot complete task, 5=completes task as well as the unaffected side). This measure has been shown to have good inter/intra reliability and validity (Singh et al. 2015; Brogardh et al. 2007).

Stroke Upper Limb Capacity Scale (SULCS): Is a measure of basic arm capacities and overall arm strength in stroke survivors. The measure consists of 10 functional tasks (e.g. carrying a briefcase, typing on a computer, writing on a notepad). These tasks are then subdivided into 3 areas: upper limb capacity with no control from wrist and fingers, upper limb capacity with basic control from wrist and fingers, and upper limb capacity with advanced control from wrist and fingers. Each task is then scored on a 3-point scale (0=cannot complete task, 2=completes task as well as the unaffected side). This measure has been shown to have good reliability and concurrent validity (Houwink et al. 2011; Roorda et al. 2011).

University of Maryland Arm Questionnaire (UMAQ): Is a measure of gross functional dexterity in the upper arm for stroke survivors. The measure consists of 10 functional tasks (e.g. opening/closing jars, opening/closing doors, reaching and grabbing common household items). Each task is then scored on a 6-point scale (0=cannot complete task, 5=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Beebe et al. 2009, Bovend' Eerdt et al. 2002)**.**

Upper Extremity Function Test (UEFT): Is a measure of total upper extremity dexterity and function in stroke survivors. The measure consists of 15 functional tasks (e.g. moving a jar around, stacking coins, reaching and grabbing a cup). There are 3 subsections of the UEFT: (speed of execution, functional rating, task analysis). Each task is then measured on a 6-point scale (-3=cannot complete task, +3=completes task as well as the unaffected side). This measure has good test/re-test reliability and validity (Platz et al. 2009; Feys et al. 2002).

Wolf Motor Function Test (WMFT): Is a measure that quantifies upper extremity motor ability in stroke survivors. The measure consists of 17 tasks (e.g. lifting arm up using only shoulder abduction, picking up a pencil, picking up a paperclip). These tasks are then subdivided into 3 areas: functional tasks, measures of strength, and quality of movement. Patients are scored on a 6-point scale (1=cannot complete task, 6=completes task as well as the unaffected side. This measure has been shown to have good reliability and validity (Wolf et al. 2005; Wolf et al. 2001).

Dexterity

Box and Block Test (BBT): Is a measure of gross unilateral manual dexterity in stroke survivors. This measure consists of 1 functional task. This task involves a patient moving as many wooden blocks as possible from one end of a partitioned box to the other, in a span of 60 seconds. Patients are scored based on the number of blocks they transfer (the higher the blocks transferred, the better the outcome). The measure has been shown to have good reliability and validity. (Higgins et al. 2005; Platz et al. 2005).

Finger to Nose Test (FNT): Is a measure of overall manual dexterity in stroke survivors. This measure consists of 1 functional task. This task involves the patient touching their index finger to their nose as 10 times as fast as possible. This task is then repeated 1 additional time. Patients are scored based on the number of times they touch their nose (the faster the time the better the outcome). The measure has been shown to have good reliability and construct plus concurrent validity (Rodrigues et al. 2017)

Grating Orientation Task (GOT): Is a measure of overall tactile spatial acuity in stroke survivors. This measure consisted of 1 functional task. Patients were asked to differentiate between a smooth and grooved surface that was placed both proximally and then distally from the patient. This process is repeated 10 different times. Patients are scored based on the number of times they successfully identify the type of surface (the higher the rate of identification, the better the outcome). This measure has been shown to have good reliability and validity (Craig 1999).

Grooved Pegboard Test (GPT): Is a measure of fine motor control in stroke survivors. This measure consists of 1 functional task. Patients are asked to place 25 pegs into the grooved pegboard and are typically given 5-10 minutes to do so. The patients are then scored based on the number of pegs inserted and the time it took them to do so (the higher the insertion rate and the lower the time, the better the outcome). This measure has been shown to have good reliability and validity (Lee et al. 2016; Thompson-Butel et al. 2014).

Minnesota Manual Dexterity Test (MMDT): Is a measure of fine motor control and general dexterity in stroke survivors. The measure consists of 2 functional tasks. Patients are asked to place wooden discs instead of a cylindrical object for the first task. Then, they are asked to turn the discs clockwise 180 degrees and told to shut the lid on the cylinder. Patients are scored on the amount discs inserted and on the screwing of the lid. The higher the number of discs put in the cylinder and the faster/tighter the lid is screwed on, the better the outcome. This measure has been shown to have good reliability and validity (Wang et al. 2018; Surrey et al. 2003).

Nine Hole Peg Test (9HPT): Is a measure of overall manual dexterity in stroke survivors. The measure consists of 1 functional task. Patients are asked to take 9 pegs

out of a container and insert them into the pegboard. Once all 9 pegs are inserted they are then taken out of the pegs as quickly as possible and placed back in the container. Patients are scored on how quickly they can insert and take out the pins, so the faster the time, the better the outcome. This measure has been shown to have good reliability and concurrent validity (da Silva et al. 2017).

Purdue Pegboard Test (PPT): Is a measure of precision grip strength and speed in stroke survivors. The measure consists of 1 functional task. Patients are asked to place as many pins as they can onto the pegboard in 30 secs, and then repeat this exercise for their other hand. Patients are scored on the number of pins they can place onto the pegboard in the given amount of time. This measure has been shown to have good reliability and validity (Gonzalez et al. 2017, Wittich & Nadon, 2017).

Activities of daily living

Arm Motor Ability Test (AMAT): Is a measure of upper extremity limitation for stroke survivors in performing activities of daily living. The measure consists of 13 common unilateral and bilateral tasks (e.g. manipulating objects such as utensil and telephones; donning/doffing a piece of clothing). Each task is scored on two, 6-point ordinal scales assessing functional ability and the quality of the movement performed. The measure has been shown to have good reliability and construct validity, in its full form and in abbreviated versions for stroke survivors (Fulk et al. 2017; O'Dell 2013; O'Dell 2011).

Assessment of Motor and Process Skills (AMPS): Is a measure of processing skills and overall independence for stroke survivors in performing activities of daily living (ADL) (Ahn et al. 2016). The measure consists of 16 motor tasks (e.g. picking up/setting down a mug, donning/doffing a piece of clothing, turning doorknobs) and 20 process tasks (e.g.memory testing, matching shapes, word recall) (Ahn et al. 2016) Each task is scored on 10 item tool assessing functional ability and the accuracy/speed at which the skill(s) are completed (Lam et al. 2018). This measure has been shown to have good reliability and validity in both its full and abbreviated form (Lam et al. 2018; Ahn et al. 2016).

Barthel Index (BI): Is a measure of how well a stroke survivor can function independently and how well they can perform activities of daily living (ADL). The measure consists of a 10-item scale (e.g. feeding, grooming, dressing, bowel control). Possible total scores range from 0 to 100. This measure has been shown to have good reliability and validity in its full form (Gonzalez et al. 2018; Park et al. 2018).

ABILHAND: Is a measure of how well a stroke survivor utilizes their hands to complete various manual tasks. The measure consists of 23 common bimanual activities (e.g. hammering a nail, wrapping gifts, cutting meat, buttoning a shirt, opening mail). Each task is then scored on a 3-point scale (0=impossible, 1=difficult, 2=easy) assessing overall ability. This measure has been shown to have good reliability and validity in its full form (Ashford et al. 2008; Penta et al. 2001).

Canadian Occupational Performance Measure (COPM): Is a measure of how well a stroke survivor engages in self-care, productivity and leisure. The measure consists of 25 functional items/tasks (e.g. bathing, ability to work at least part-time, activities involved in). Each task is then scored on a single 10-point rating scale primarily measuring proficiency in each of the 3 sub-categories (self-care, productivity and leisure). This measure has been shown to have good reliability and validity in its full form. (Yang et al. 2017).

Chedoke Arm and Hand Activity Inventory (CAHAI): Is an upper limb measure that uses a 13-point quantitative scale in order to assess recovery of the arm and hand in performing activities of daily living after a stroke. It is a performance test using 13 bimanually performed real-life items, designed to encourage bilateral upper limb use.

Scores represent the patient's relative ability to independently perform stabilisation or manipulation in ADL with the impaired upper limb. The measure is shown to have good test-retest and interrater reliability, as well as good construct and concurrent validity (Ward et al. 2019; Schuster-Amft et al. 2018; Barteca et al. 2004).

Duruoz Hand Index (DHI): Is a measure used to assess hand-related activity limitation based on questions concerning activities in a person's daily life. It contains 18 activities commonly performed by the hand in the kitchen, during dressing, while performing personal hygiene, while performing office tasks, and other general items. The measure is shown to have good construct validity, test-retest reliability, and internal consistency in patients with stroke (Sezer et al. 2007).

Frenchay Arm Test (FAT): Is a measure of the upper extremity motor control that a stroke survivor possesses. The measure consists of 5 common tasks that require use of the upper extremity (e.g. stabilize a ruler/draw a line with a pencil, comb hair, clip a clothespin onto the edge of a table, grasp a cylinder, drink from a glass of water and then set it down). Each task is then scored on a 2-point scale wherein each task receives either a 0 (unsuccessful completion) or a 1 (successful completion). This measure has been shown to have good reliability and validity in its full form. (Heller et al. 1987; Parker et al. 1986)

Frenchay Activities Index (FAI): Is a measure of activities that stroke survivors have participated in recently. The measure consists of 15 items that are in turn split up into 3 subscales (domestic chores, leisure/work and outdoor activities). These items include: preparing meals, washing clothes, light/heavy housework, social outings etc. Each task is then scored on a 4-point scale with 1 being the lowest score. This measure has been shown to have good reliability and concurrent validity in its full form (Schuling et al. 1993)

Functional Activity Scale (FAS): Is a measure of functional everyday activities that stroke survivors participate in daily. The measure consists of 15 functional activities (e.g. cooking, cleaning, zipping up a coat). Each activity is then scored on a 5-point scale (0=cannot complete activity, 4=completes activity as well as the unaffected side). This measure has been shown to have good reliability and validity (Pang et al. 2006).

Functional Independence Measure (FIM): Is an 18-item outcome measure composed of both cognitive (5-items) and motor (13-items) subscales. Each item assesses the level of assistance required to complete an activity of daily living on a 7-point scale. The summation of all the item scores ranges from 18 to 126, with higher scores being indicative of greater functional independence. This measure has been shown to have excellent reliability and concurrent validity in its full form (Granger et al. 1998, Linacre et al. 1994; Granger et al. 1993).

Goal Attainment Scale (GAS): Is a measure that quantifies the progress made towards obtaining personalized rehabilitation goals. The measure consists of 5 levels of goal achievement. The items in these levels consist of various goals individual patients

would like to achieve (e.g. bathing independently, being able to do housework, walking unaided). The patient is then rated on a 4-point scale on their ability to carry out said goals (-2=far behind schedule, +2=far ahead of schedule). This measure has been found to have good reliability and validity in its full form (Hanlan et al. 2017; Krasny-Pacini et al. 2016)

Modified Barthel Index (MBI): Is a measure of how well a stroke survivor can function independently and how well they can perform activities of daily living (ADL). The measure consists of a 10-item scale (e.g. feeding, grooming, dressing, bowel control). Possible scores range from 0 to 20. This measure has been shown to have good reliability and validity in its full form. (MacIsaac et al. 2017; Ohura et al. 2017).

Motor Activity Log (MAL): Is a patient-reported measure of the use and quality of movement of the impaired arm. The measure consists of 30 functional tasks (e.g. handling utensils, buttoning a shirt, combing hair). Each task is then measured on a 6-point scale (0=complete inability to use affected arm). This measure has been shown to have good reliability and validity (Chuang et al. 2017).

Motor Assessment Scale (MAS): Is a performance-based measure that assesses everyday motor function. The measure consists of 8 motor-function based tasks (e.g. supine lying, balanced sitting, walking). Each task is then measured on a 7-point scale (0=suboptimal motor performance, 6=optimal motor performance). This measure has been shown to have good reliability and concurrent validity (Simondson et al. 2003).

Nottingham Extended Activities of Daily Life (NEADL): Is a measure of a stroke survivor's independence with regards to their performance on various activities of daily living. The measure consists of 22 functional tasks (e.g. walking, cooking, cleaning, participation in active hobbies). These tasks are then further divided into 4 distinct subscales (mobility, kitchen, domestic, and leisure activities). In turn, each task is measured on a 5-point (0=not at all, 4=on my own with no difficulty). This measure has been shown to have good reliability and validity (das Nair et al. 2011; Sahin et al. 2008).

Nottingham Stroke Dressing Assessment (NSDA): Is a measure of a stroke survivor's ability to successfully dress themselves. The measure consists of 25 functional dressing tasks (e.g. buttoning up a shirt, buckling a belt/watch, putting on pants). These tasks are then measured on a 4-point scale (0=cannot complete task, 3=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Walker et al. 2011).

Stroke Impact Scale (SIS): Is a patient-reported measure of multi-dimensional stroke outcomes. The measure consists of 59 functional tasks (e.g. dynamometer, reach and grab, walking, reading out loud, rating emotional regulation, word recall, number of tasks completed, and shoe tying). These tasks are then divided into 8 distinct subscales which include: strength, hand function, mobility, communication, emotion, memory, participation and activities of daily living (ADL). Each task is measured on a 5-point

scale (1=an inability to complete the task, 5=not difficult at all). The measure has been shown to have good reliability and validity (Mulder et al. 2016; Richardson et al. 2016).

STAIS Stroke Questionnaire (SSQ): Is a measure of activities and participation in the physical environment for stroke survivors. The measure consists of 36 functional tasks (e.g. taking a bath or shower, ability to handle your finances, opening and closing doors). Each task is measured on a 4-point scale (1=no ability, 4=complete ability). The measure has been shown to have good reliability and concurrent validity (Bouffioulx et al. 2010 Bouffioulx et al. 2008)

Upper Limb Self-Efficacy Test (UPSET): Is a measure of a stroke survivor's confidence in their ability to carry out upper limb specific tasks with their affected side. The measure consists of 20 functional tasks (e.g. shaking hands, flipping a coin, opening/shutting doors). Each task is then measured on a 5-point scale (0=cannot complete task, 4=completes task as well as the unaffected side). The measure has been shown to have good test/retest reliability and validity (Abdullahi, 2016; Pang et al. 2007).

Spasticity

Ashworth Scale (AS): Is a measure of resistance to passive movement in stroke survivors. The measure contains 15 functional m'ovements which are done with the guidance of a trained clinician. These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 5-point scale (0=no increase in muscle tone, 1=barely discernible increase in muscle tone, 2=moderate increase in muscle tone 3=profound increase in muscle tone (movement of affected limb is difficult) 4=complete limb flexion/rigidity (nearly impossible to move affected limb)). This measure has been shown to have good reliability and validity (Merholz et al. 2005; Watkins et al. 2002).

Bhakta Finger Flexion Scale (BFFS): Is a measure of the overall finger flexion experienced by stroke survivors when completing functional tasks. This measure consists of 27 functional tasks (e.g. writing with a pen, typing, squeezing a ball). Each task is then rated on a 3-point scale (0=cannot complete task; fingers too rigid, 2=easily completes task; flexes and extends fingers). This measure has been shown to have good reliability and validity (Christina et al. 2015).

Disability Assessment Scale (DAS): Is a measure of resistance to passive movement in the upper extremity for stroke survivors. The measure consists of 20 functional tasks (e.g. brushing teeth, buttoning a shirt, gait technique & general pain). These tasks are then divided into 4 sections: hygiene, dressing, limb position and pain. Each task is then rated from: 0=no disability, 1=mild disability 2=moderate disability, 3=severe disability. This measure has been shown to have good reliability and validity (Thibaut et al. 2013; Brashear et al. 2002)

Modified Ashworth Scale (MAS): Is a measure of muscle spasticity for stroke survivors. The measure contains 20 functional movements which are done with the guidance of a trained clinician. These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 6-point scale (0=no increase in muscle tone, 1=barely discernible increase in muscle tone 1+=slight increase in muscle tone, 2=moderate increase in muscle tone 3=profound increase in muscle tone (movement of affected limb is difficult) 4=complete limb flexion/rigidity (nearly impossible to move affected limb)). This measure has been shown to have good reliability and validity (Merholz et al. 2005; Blackburn et al. 2002).

Modified Tardieu Scale (MTS): Assesses spasticity through measuring the quality and angle of muscle movements in response to stretches of different velocities. The velocities of muscle movement are as slow as possible (V1), speed of the limb falling from gravity (V2), and when the joint is moved as fast as possible (V3). The quality and angle of muscle reactions are recorded during these velocities. The quality of muscle reactions are scored as: 0 (no resistance throughout the duration of the stretch), 1 (slight resistance), 2 (clear catch occurring at a precise angle, followed by a release), 3 (fatigable clonus), 4 (infatigable clonus), 5 (joint is immovable) (Li et al. 2014b).

Resistance to Passive Movement Scale (REPAS): Is a measure of general muscle spasticity for stroke survivors. The measure contains 52 functional movements which are done with the guidance of a trained clinician. These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 5-point scale (0=no increase in muscle tone, 1=barely discernible increase in muscle tone, 2=moderate increase in muscle tone 3=profound increase in muscle tone (movement of affected limb is difficult) 4=complete limb flexion/rigidity (nearly impossible to move affected limb)). This measure has been shown to have good test/retest reliability and concurrent validity (Platz et al. 2008).

Spasm Frequency Scale (SFS): Is a measure of the amount of spasms experienced by stroke survivors in a day. The measure is only concerned with measuring the amount of spasms in a single day. The amount of spasms per day are rated based on a 5-point scale (0=No spasms. 1= One or fewer spasms per day 2=Between 1 and 5 spasms per day 3=Five to less than 10 spasms per day 4=Ten or more spasms per day, or continuous contraction). This measure has been shown to have good reliability and validity (Santamato et al. 2013; Snow et al. 1990).

Range of motion

Active Range of Motion (AROM): Is a measure of the range of motion stroke survivors possess without receiving assistance. The measure consists of 20 functional movements for both the upper and lower extremity. The movements are evenly divided into 2 sections: upper extremity and lower extremity. These movements are then rated on a 4-point ordinal scale (0=cannot complete movement, 3=completes movement as well as the unaffected side). This measure has been shown to have good reliability and validity (Beebe & Lang 2009, Dickstein et al. 1986)

Maximal Elbow Extension Angle During Reach (MEEAR): Is a measure of the amount of elbow extension undergone by a stroke survivor while they are reaching for an object. The measure consists of 1 functional movement which is when a patient reaches for an object and their rate of elbow extension is measured (the higher the rate of extension, the better the outcome). This measure has been shown to have good inter/intra reliability and concurrent validity (Murphy et al. 2011; Cristea et al. 2003).

Passive Range of Motion (PROM): Is a measure of the range of motion stroke survivors possess while receiving assistance. The measure consists of 30 functional movements for both the upper and lower extremity. The movements are evenly divided into 2 sections: upper extremity and lower extremity. These movements are then rated on a 5-point ordinal scale (0=cannot complete movement, 4=completes movement as well as the unaffected side). This measure has been shown to have good test/retest reliability and validity (Lynch et al. 2005).

Proprioception

Joint Position Sense Test (JPST): Is a measure of how well stroke survivors can perceive the position of their joints in motion and standing still. The measure consists of 1 functional task repeated several times. This task involves the patient holding 2 different shaped objects that also weigh different from each other and then told to identify which one weighs more and which one has a stranger shape. The more times the patient (s) identifies which shape is heavier/unique, then the better the outcome. This measure has been shown to have good reliability and validity (Kattenstroth et al. 2013).

Kinesthetic Visual Imagery Questionnaire (KVIQ): Is the measure of the visual acuity and muscle movement that stroke survivors possess. The measure consists of 20 functional tasks (e.g. tying shoes, reading out loud, reaching for an object, peripheral vision testing). Each task is then measured on 3-point scale (0=cannot complete task, 2=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Salles et al. 2017; Demanboro et al. 2018).

Revised Nottingham Sensory Assessment (RNSA): Is a measure of somatosensory perception in stroke survivors. The measure consists of 1 functional task repeated with 11 different objects. The task involves patients identifying 11 different objects with their eyes closed. The higher the rate of objects identified leads to a better overall outcome. This measure is shown to have good reliability and validity (Boccuni et al. 2018; Gorst et al. 2018).

Stroke severity

Modified Rankin Scale (MRS): Is a measure of functional independence for stroke survivors. The measure contains 1 item. This item is an interview that lasts approximately 30-45 minutes and is done by a trained clinician. The clinician asks the patient questions about their overall health, their ease in carrying out ADLs (cooking, eating, dressing) and other factors about their life. At the end of the interview the patient is assessed on a 6-point scale (0=bedridden, needs assistance with basic ADLs, 5=functioning at the same level as prior to stroke). This measure has been shown to have good reliability and validity (Quinn et al. 2009; Wilson et al. 2002).

National Institutes of Health Stroke Scale (NIHSS): Is a measure of somatosensory function in stroke survivors during the acute phase of stroke. This measure contains 11 items and 2 of the 11 items are passive range of motion (PROM) assessments delivered by a clinician to the upper and lower extremity of the patient. The other 9 items are visual exams conducted by the clinician (e.g. gaze, facial palsy dysarthria, level of consciousness). Each item is then scored on a 3-point scale (0=normal, 2=minimal function/awareness). This measure has been shown to have good reliability and validity (Heldner et al. 2013; Weimar et al. 2004).

Neurological Function Deficit Scale (NFDS): Is a measure of neurological deficits experienced by stroke survivors in both the upper and lower extremities. This measure contains 40 functional movements done with the guidance of a clinician (e.g. should abduction, shoulder adduction, leg flexion/extension). These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then measured on a 6-point scale (0=normal function, 5=severe stroke). This measure has been shown to have good test/retest reliability and validity (Yao & Ouyang. 2014).

Muscle strength

Hand Grip Strength (HGS): Is a measure of the overall hand grip strength in stroke survivors. The measure consists of 1 functional task. This task involves a patient squeezing the dynamometer and then receiving a hand grip strength measurement. This action is then repeated 1 additional time and the best of the two readings is used as a score. This measure has been shown to have good test/retest reliability and validity (Bertrand et al. 2015).

Isokinetic Peak Torque (IPT): Is a measure of the work capacity of specific muscle groups of a stroke survivor. The measure consists of 1 functional task. The patient performs elbow flexion/extension while attached to a machine that measures force output. The process is then repeated for the leg. The output is then compared to healthy patients that are approximately the same age and build. This measure has been shown to have good test/retest reliability (Horvat et al. 1997).

Manual Muscle Strength Test (MMST): Is a measure of how well a stroke survivor can complete various upper extremity movements while resistance is applied by a trained clinician. The measure consists of 3 functional tasks: muscle contraction, total range of motion and resistance to applied pressure. Patients are scored on a 12-point scale (0=no movement, T=trace/barely discernable movement, 10=movement carried out as well as the unaffected side). This measure has been shown to have good reliability and validity (Kristensen et al. 2017; Ada et al. 2016)

Medical Research Council Scale (MRCS): Is a measure of overall muscle strength a stroke survivor possesses. The measure consists of 33 functional tasks (e.g. opening/shutting cupboards, screwing and unscrewing lids, lifting of light objects). Each task is then rated on a 4-point scale (0=cannot complete task, 3=completes task as well as the unaffected side). This measure has been shown to have good reliability and validity (Hsieh et al. 2011; Fasoli et al. 2004).

Therapy based interventions

Neurodevelopmental techniques

Adopted from: http://www.bobathconcept.eu/en/main-site/

There are several approaches that are considered to be neurodevelopmental techniques (NDT). These include the Bobath concept, Brunnstrom movement therapy and motor relearning programmes.

The Bobath concept is a comprehensive, problem-solving treatment approach that focuses on motor recovery (e.g. function, movement and tone) of an individual's affected side after a lesion in the central nervous system (Michielsen et al. 2017). Prior to its introduction in the 1950's, stroke rehabilitation largely assumed a compensatory approach towards the unaffected side for rehabilitation (Kollen et al. 2009). The Bobath concept like other neurodevelopmental techniques relies on the tenets of neuroplasticity, in that motor recovery of the affected side is possible through individualised treatment plans that focus on how tasks are completed, facilitation of movements through therapeutic handling, movement analysis, modification of the environment and appropriate use of verbal cues from therapists (Michielsen et al. 2017).

Brunnstrom movement therapy focuses on retraining motor movements through emphasis of the synergistic and reflexive muscle movements that develop during recovery from hemiplegia. The approach encourages the use of abnormal or spastic muscle movements of the flexors and extensors during early recovery to regain muscle synergies, contrary to the Bobath concept which inhibits these movements (Pandian 2012; Brunnstrom 1970).

The motor relearning programme employs practice of task-specific activities to remediate specific motor skills needed to perform that task. Motor tasks are practiced in context relevant environments to enhance sensory input and modulate performance (Pandian 2012).

A total of 9 RCTs were found that evaluated neurodevelopmental techniques for upper extremity motor rehabilitation, interventions categories are listed below.

Three RCTs compared the Bobath concept to conventional therapy (van der Lee et al. 1999; Gelber et al. 1995; Basmajian et al. 1987). Two RCTs compared motor relearning programmes to conventional therapy (Walker et al. 2012; Platz et al. 2009). Three RCTs compared motor relearning programmes to Bobath concept approaches (Langhammer and Stanghelle, 2011; Platz et al. 2005; van Vliet et al. 2005). One RCT compared Brunnstrom movement therapy to a motor relearning programme (Pandian et al. 2012).

The methodological details and results of all 9 RCTs are presented in Table 1.

Table 1. RCTs evaluating neurodevelopmental techniques for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Bobath concept approach compared to conventional therapy		
van der Lee et al. (1999) RCT (7) N_{start}=66 N_{end}=57 TPS=Chronic	E: Bobath concept C: Forced-use therapy Duration: 6h, 5d/wk for 2wk	• Action Research Arm Test (+con)
Gelber et al. (1995) RCT (5) N_{start}=20 N_{end}=20 TPS=Acute	E: Bobath concept C: Traditional techniques Duration: *Not reported*	• Functional Independence Measure (-) • Box and Block Test (-) • Nine Hole Peg Test (-)
Basmajian et al. (1987) RCT (6) N_{start}=29 N_{end}=23 TPS=Sub-acute	E: Bobath concept C: Physical and behavioural therapy using EMG Duration: 45min, 3d/wk for 5wk	• Upper Extremity Performance Test for the Elderly (-) • Finger Oscillation Test (-)
Motor relearning programmes compared to conventional therapy		
Walker et al. (2012) RCT (7) N_{Start}=70 N_{End}=64 TPS=Acute	E: Motor relearning programme C: Dressing without a task-oriented approach Duration: 3d/wk for 6wk	• Nottingham Stroke Dressing Assessment (-) • 10-hole peg transfer test (-)
Platz et al. (2009) RCT (8) N_{start}=148 N_{end}=135 TPS=Not reported	E: Motor relearning programme E2: Passive therapy (with splints) C: Conventional therapy Duration: 45min, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Upper Extremity Performance Test for the Elderly (-)
Motor relearning programme compared to Bobath concept approaches		
Langhammer & Stanghelle (2011). RCT (8) N_{start}=61 N_{end}=53 TPS=Not reported	E: Motor relearning programme E2: Bobath concept Duration: 40min, 5d/wk for 2wk	• Motor Assessment Scale (+exp) • Sodring Motor Evaluation Scale (+exp) • Motor Activity Log (+exp)
Platz et al. 2005 RCT (8) N_{start}=62 N_{end}=62 TPS=Subacute	E: Motor relearning programme (Arm BASIS) E2: Bobath concept C: No augmented exercise therapy time Duration: 4wk	• Fugl-Meyer Assessment (-)
van Vliet et al. (2005) RCT (7) N_{start}=120	E: Motor Relearning Programme E2: Bobath concept Duration: 23min, 5d/wk for 4wk	• Motor Assessment Scale (-)

N_{end}=105 TPS=Acute		
Brunnstrom movement therapy vs Motor relearning programme		
Pandian et al. (2012) RCT (6) N_{start}=30 N_{end}=30 TPS=Chronic	E: Brunnstrom hand manipulation treatment C: Motor relearning programme Duration: 1h, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about neurodevelopmental techniques

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Bobath concept approaches** may not have a difference in efficacy when compared to **conventional therapy** for improving motor function.	2	Van der lee et al. 1999; Basmajian et al. 1987
1b	**Motor relearning programmes** may not have a difference in efficacy when compared to **conventional therapy** for improving motor function.	1	Platz et al. 2009
1a	There is conflicting evidence about the effect of **motor relearning programmes** to improve motor function when compared to **Bobath concept approaches**.	2	Langhammer Stanghelle et al. 2011; Platz et al. 2005
1b	**Brunnstrom movement therapy** may produce greater improvements in motor function than **motor relearning programmes**.	1	Pandian et al. 2012

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Bobath concept approaches** may not have a difference in efficacy when compared to **conventional therapy** for improving performance of activities of daily living.	1	Gelber et al. 1995
1b	**Motor relearning programmes** may not have a difference in efficacy when compared to **conventional therapy** for improving performance of activities of daily living.	1	Walker et al. 2012
1a	There is conflicting evidence about the effect of **motor relearning programmes** to improve performance of activities of daily living when compared to **Bobath concept approaches**.	2	Langhammer Stanghelle et al. 2011; Van Vliet et al. 2005

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Bobath concept approaches** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	1	Gelber et al. 1995
1b	**Motor relearning programmes** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	1	Walker et al. 2012

Key points

Bobath concept approaches and motor relearning programmes may not be beneficial for upper limb rehabilitation following stroke.

Brunnstrom movement therapy may be more beneficial than motor relearning programmes for upper limb function.

Bilateral arm training

Adopted from: https://www.newswise.com/articles/stroke-survivors-rehab-arms-with-in-home-device

Bilateral arm training is a technique whereby patients perform the same movements with both the right and left upper limbs simultaneously. The use of bilateral arm training techniques with the upper limb following stroke has been encouraged recently with the development of new theories regarding neural plasticity. Theoretically, the use of the intact limb helps to promote functional recovery of the impaired limb through facilitative coupling effects between the damaged and intact cerebral hemispheres through neural networks linked via the corpus callosum (Morris et al. 2008; Summers et al. 2007).

Interventions for bilateral arm training included: 13 RCTs evaluating bilateral arm training compared to unilateral arm training (Han and Kim, 2016; Shim et al. 2015; McCombe et al. 2014; Byl et al. 2013; Dispa et al. 2013; Kim et al. 2013; Wu et al. 2013; Morris and van Wijck, 2012; Yang et al. 2012; Lin et al. 2010; Stoykov et al. 2009; Morris et al. 2008; Summers et al. 2007). Five RCTs evaluating bilateral arm training compared to conventional rehabilitation (Meng et al. 2018; Lee et al. 2017; Lee et al. 2013; Stinear et al. 2008; Desrosiers et al. 2005). Two RCTs evaluating bilateral arm training with rhythmic auditory cueing compared to unilateral arm training or conventional rehabilitation (Whitall et al. 2011; Luft et al. 2004), and task-oriented bilateral arm training (Hsieh et al. 2016; Song et al. 2015). A single RCT looked at bilateral arm training compared to TENS (Stinear et al. 2014); while two RCTs looked at EMG-triggered NMES bilateral arm training (Singer et al. 2013; Cauraugh and Kim, 2003). Two RCTs looked at bilateral arm training compared to CIMT (Brunner et al. 2012; Wu et al. 2011), and another two compared bilateral arm training with rhythmic auditory cueing to modified CIMT (van Delden et al. 2015; van Delden et al. 2013).

The methodological details and results of all 29 RCTs evaluating bilateral arm training for the upper extremity motor rehabilitation are presented in Table 2.

Table 2. RCTs evaluating BAT interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Bilateral arm training compared to unilateral arm training		
Han & Kim (2016) RCT (5) N_{Start}=25 N_{End}=25 TPS=Not reported	E: Bilateral arm training C: Unilateral arm training Duration: 5x/wk for 6wk	• Box and Block Test (-) • Elbow Amplitude (-) • Shoulder Amplitude (+exp)
Shim et al. (2015) RCT (6) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Bilateral training C: Unilateral training Duration: 30min, 5x/wk for 6wk	• Motor Function Test (+exp) • Functional Independence Measure (+exp) • Affected hand amount of sedentary and moderate activity (+exp)
McCombe et al.(2014) RCT (7) N_{Start}=30 N_{End}=26 TPS=Subacute	E: Bilateral + Unilateral training C: Unilateral training Duration: 1h, 3d/wk for 12wk	• Wolf Motor Function Test (+exp) • University of Maryland Arm Questionnaire (+exp) • Fugl-Meyer Assessment (-) • Box and Block Test (-)
Byl et al. (2013) RCT (5) N_{Start}=18 N_{End}=15 TPS=Subacute	E: Bilateral orthosis C: Unilateral orthosis Duration: 90 min for 12 sessions	• Fugl-Meyer Assessment (-)
Dispa et al. (2013) RCT (7) N_{Start}=10 N_{End}=10 TPS=Not given	E: Bilateral therapy C: Unilateral therapy Duration: 1h, 3d/wk for 4wk	• Fugl-Meyer Assessment (-) • Purdue pegboard Test (-) • ABILHAND scale (-) • STAIS-stroke questionnaire (-)
Kim et al. (2013) RCT (3) N_{start}=15 N_{end}=15 TPS=Subacute	E1: Bilateral robotic training E2: Unilateral robotic training C: Usual Care Duration: 90min, 2d/wk for 6wk	• Fugl-Meyer Assessment (-)
Wu et al. (2013c) RCT (7) N_{Start}=53 N_{End}=53 TPS=Chronic	E1: Bilateral robotic training E2: Unilateral robotic training C: Conventional therapy Duration: 90 to 105min, 1d/wk for 4wk	• Motor Activity Log (-) • Wolf Motor Function Test (-) • ABILHAND Scale (-)
Morris & van Wijck (2012) RCT (7) N_{start}=106 N_{end}=85 TPS=Not reported	E: Bilateral training C: Unilateral training Duration: 20min, 5d/wk for 6wk	• 9 Hole Peg Test (+exp) • Action Research Arm Test (-)
Yang et al. (2012) RCT (7) N_{start}=21 N_{end}=21 TPS=Chronic	E1: Unilateral robot assisted training E2: Bilateral robot assisted training C: Standard training group Duration: 90min, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Medical Research Council Scale (-)
Lin et al. (2010) RCT (6) N_{start}=33	E: Bilateral training C: Unilateral training Duration: 2h, 5d/wk for 3wk	• Fugl Meyer Assessment (+exp) • Functional Independence Measure (-) • Motor Assessment Log (-)

N_{end}=33 TPS=Chronic		
Stoykov et al. (2009) RCT (5) N_{start}=21 N_{end}=21 TPS=Chronic	E: Bilateral training C: Unilateral training Duration: 1h, 3d/wk for 8wk	• Motor Assessment Scale (-) • Motor Status Scale (-)
Morris et al. (2008) RCT (7) N_{start}=106 N_{end}=85 TPS=Chronic	E: Bilateral training C: Unilateral training Duration: 20min, 5d/wk for 6wk	• Arm Research Arm Test (-) • Rivermead Motor Assessment (-) • 9 Hole Peg Test (+exp) • Modified Barthel Index (-)
Summers et al. (2007) RCT (5) N_{start}=12 N_{end}=10 TPS=Chronic	E: Bilateral training C: Unilateral training Duration: *Not reported*	• Modified Motor Assessment Scale (+exp)
Bilateral arm training compared to conventional rehabilitation		
Meng et al. (2018) RCT (7) N_{start}=128 N_{end}=123 TPS=Acute	E: Hand-Arm Bimanual Intensive Therapy C: Conventional Rehabilitation Program Duration: 1h (twice per d), 5d/wk for 2wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp)
Lee et al. (2017) RCT (6) N_{Start}=30 N_{End}=30 TPS=Chronic	E: Bilateral Arm Training C: Upper Extremity Training Duration: 1h, 5d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp) • Modified Barthel Index (+exp)
Lee et al. (2013) RCT (6) N_{Start}=26 N_{End}=26 TPS=Chronic	E: Bilateral training + conventional rehabilitation C: Conventional rehabilitation Duration: 30min, 3d/wk for 4wk	• Functional Independence Measure (+exp)
Stinear et al. (2008) RCT (6) N_{start}=32 N_{end}=27 TPS= Chronic	E: Bilateral training C: Self-directed motor practice Duration: 10min (three times per day), 7d/wk for 4wk	• Fugl Meyer Assessment (+exp) • Grip strength (-)
Desrosiers et al. (2005) RCT (7) N_{start}=41 N_{end}=33 TPS=Subacute	E: Bilateral training C: Conventional therapy Duration: 45min, 15-20 sessions	• Fugl Meyer Assessment (-) • Grip strength (-) • Box and Block Test (-) • Purdue Pegboard Test (-) • Finger-to-Nose Test (-) • Upper Extremity Performance test for the Elderly (-) • Functional Independence Measure (-) • The Assessment of Motor and Process Skills (-)
Bilateral arm training with rhythmic auditory cueing compared to unilateral arm training or conventional rehabilitation		
Whitall et al. (2011) RCT (6) N_{Start}=111 N_{End}=92 TPS=Chronic	E: Bilateral arm training with rhythmic auditor cueing C: Dose matched unilateral therapeutic exercises Duration: 20min, 3d/wk for 6wk	• Fugl Meyer Assessment (-) • Wolf Motor Function Test (-) • Stroke Impact Scale (-) • Elbow extension (-) • Shoulder extension (-) • Wrist extension (+exp) • Elbow flexion (-)
Luft et al. (2004) RCT (7) N_{start}=26 N_{end}=21 TPS=Chronic	E: Bilateral arm training + rhythmic auditory cueing C: Therapeutic exercises. Duration: 1 h, 3d/wk for 6wk	• Fugl Meyer (-) • Wolf Motor Arm Test (-) • University of Maryland Arm Questionnaire for Stroke (-) • Elbow Strength (-) • Shoulder Strength (-)
Task-oriented bilateral arm training compared to task-oriented training or bilateral arm training with rhythmic auditory cueing		

Hsieh et al. (2016) RCT (6) N_{Start}=31 N_{End}=31 TPS=Subacute	E: Bilateral arm priming + task-oriented training C: Task-oriented training alone Duration: 90min, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Box and Block Test (-) • Grip Strength (-) • Modified Rankin Scale (-) • Functional Independence Measure (-) • Activities of Daily Living (-) • Stroke Impact Scale (+exp)
Song et al. (2015) RCT (5) N_{Start}=40 N_{End}=40 TPS=Chronic	E: Task-oriented bilateral arm training E2: Bilateral arm training with rhythmic auditory cueing Duration: 30min, 5d/wk for 12wk	• Box and Block Test (+exp) • Jebsen Taylor Hand Function Test (+exp) • Modified Barthel Index (+exp)
Bilateral arm training compared to TENS		
Stinear et al. (2014) RCT (6) N_{Start}=57 N_{End}=51 TPS=Not given	E: Bilateral training C: TENS Duration: 45min, 5d/wk for 4wk	• Modified Ashworth Scale (-) • Stroke Impact Scale (-)
EMG-triggered NMES with bilateral arm training compared to EMG-triggered NMES with unilateral training		
Singer et al.(2013) RCT (4) N_{Start}=24 N_{End}=21 TPS=Chronic	E: Bilateral training + EMG-triggered NMES C: Unilateral training + EMG-triggered NMES Duration: 30min, 7d/wk for 6wk	• Fugl-Meyer Assessment (-) • Arm Motor Ability Test (-)
Cauraugh & Kim (2002) RCT (5) N_{start}=25 N_{end}=25 TPS=Chronic	E: EMG-triggered NMES + bilateral training E2: EMG-triggered NMES + unilateral training C: Control Duration: 90min, 4d/wk for 2wk	E1 vs E2/C • Box and Block Test: (+exp) E2 vs C • Box and Block Test (+exp_2)
Bilateral arm training compared to CIMT		
Brunner et al. (2012) RCT (7) N_{start}=30 N_{end}=30 TPS=Not given	E: Bilateral training C: mCIMT Duration: 4h, 7d/wk for 4wk	• Action Research Arm Test (-) • 9 Hole Peg Test (-) • Motor Activity Log (-)
Wu et al. (2011) RCT (5) N_{start}=66 N_{end}=58 TPS=Chronic	E: dCIT E2: Bilateral training C: Control Duration: 2h, 5d/wk for 3wk	E/E2 vs C • Normalized Movement Unit for unilateral and bilateral task (+exp, exp_2) E2 vs C • Peak Velocity for unilateral and bilateral tasks (exp_2) E vs C • Wolf Motor Function Test (+exp) E vs E2/C • Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Peak Velocity for unilateral and bilateral tasks (-) • Normalized Movement Unit for unilateral and bilateral task (-)
Modified CIMT with unilateral training compared to rhythmic auditory cueing with bilateral arm training		
van Delden et al. (2015) RCT (6) N_{Start}=60 N_{End}=52 TPS=Subacute	E: Modified CIMT + unilateral training E2: Rhythmic auditory cueing + bilateral training C: Dose-matched Control Duration: 1h, 3d/wk for 6wk	E2 vs C • Bimanual coordination task: (+exp_2) E vs C • Unimanual reference task (+con) E vs E2 • Unimanual reference task (+exp_2)
van Delden et al. (2013) RCT (6)	E1: Modified CIMT + unilateral training E2: Rhythmic auditory cueing + bilateral training	• Action Research Arm Test (-) • Nine Hole Peg Test (-) • Motricity Index (-)

N_{Start}=60 N_{End}=55 TPS=Subacute	C: Dose-matched control group Duration: 1h, 3d/wk for 6wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-) • Stroke Impact Scale (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about bilateral arm training

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Bilateral arm training** may not have a difference in efficacy when compared to **unilateral arm training** for improving motor function.	11	Shim et al. 2015; McCombe et al. 2014; Byl et al. 2013; Dispa et al. 2013; Kim et al. 2013; Wu et al. 2013; Morris and van Wijck, 2012; Yang et al. 2012; Lin et al. 2010; Stoykov et al. 2009; Morris et al. 2008
1a	**Bilateral arm training** may produce greater improvements in motor function than **conventional therapy**.	4	Meng et al. 2018; Lee et al. 2017; Stinear et al. 2008; Desrosiers et al. 2005
1b	**Bilateral arm training with rhythmic auditory cueing** may not have a difference in efficacy when compared to **unilateral arm training or conventional therapy** for improving motor function.	2	Whiteall et al. 2011; Luft et al. 2004
1b	**Task-oriented bilateral arm training** may not have a difference in efficacy when compared to **task-oriented training** for improving motor function.	1	Hsieh et al. 2016
2	**EMG-triggered NMES with bilateral arm training** may not have a difference in efficacy when compared to **EMG-triggered NMES with unilateral arm training** for improving motor function.	1	Singer et al. 2013
1b	**Bilateral arm training** may not have a difference in efficacy when compared to **CIMT** for improving motor function.	2	Brunner et al. 2012; Wu et al. 2011
1a	There is conflicting evidence about the effect of **bilateral arm training with rhythmic auditory cueing** to improve motor function when compared to **mCIMT**.	2	Van Delden et al. 2015; Van Delden et al. 2013

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Bilateral arm training** may not have a difference in efficacy when compared to **TENS** for improving spasticity.	1	Stinear et al. 2014

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Task-oriented bilateral arm training** may not have a difference in efficacy when compared to **task-oriented training** for improvements on measures of stroke severity.	1	Hsieh et al. 2016

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Bilateral arm training** may not have a difference in efficacy when compared to **unilateral arm training** for improving dexterity.	5	Han and Kim, 2016; McCombe et al. 2014; Dispa et al. 2013; Morris and van Wijck, 2012; Morris et al. 2008
1a	There is conflicting evidence about the effect of **bilateral arm training** to improve dexterity when compared to **conventional therapy**.	2	Lee et al. 2017; Desrosiers et al. 2005
1b	**Task-oriented bilateral arm training** may not have a difference in efficacy when compared to **task-oriented training** for improving dexterity.	1	Hsieh et al. 2016
2	**Task-oriented bilateral arm training** may produce greater improvements in dexterity than **bilateral arm training with rhythmic auditory cueing**.	1	Song et al. 2015
2	**EMG-triggered NMES with bilateral arm training** may produce greater improvements in dexterity than **EMG-triggered NMES with unilateral arm training or conventional therapy**.	1	Cauraugh and Kim, 2002
1b	**Bilateral arm training** may not have a difference in efficacy when compared to **CIMT** for improving dexterity.	1	Brunner et al. 2012
1b	**Bilateral arm training with rhythmic auditory cueing** may not have a difference in efficacy when compared to **mCIMT** for improving dexterity.	1	Van Delden et al. 2013

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **bilateral arm training** to improve muscle strength when compared to **unilateral arm training**.	2	Han and Kim, 2016; Yang et al. 2012
1a	**Bilateral arm training** may not have a difference in efficacy when compared to **conventional therapy** for improving muscle strength.	2	Stinear et al. 2008; Desrosiers et al. 2005
1b	**Bilateral arm training with rhythmic auditory cueing** may not have a difference in efficacy when compared to **unilateral arm training or conventional therapy** for improving muscle strength.	2	Whiteall et al. 2011; Luft et al. 2004
1b	**Task-oriented bilateral arm training** may not have a difference in efficacy when compared to **task-oriented training** for improving muscle strength.	1	Hsieh et al. 2016

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Bilateral arm training** may not have a difference in efficacy compared to **unilateral arm training** for improving performance of activities of daily living.	7	Shim et al. 2015; Dispa et al. 2013; Wu et al. 2013; Lin et al. 2010; Stoykov et al. 2009; Morris et al. 2008; Summers et al. 2007
1a	There is conflicting evidence about the effect of **bilateral arm training** to improve performance of activities of daily living when compared to **conventional therapy**.	3	Lee et al. 2017; Lee et al. 2013; Desrosiers et al. 2005
1b	**Bilateral arm training with rhythmic auditory cueing** may not have a difference in efficacy when compared to **unilateral arm training** for improving performance of activities of daily living.	1	Whiteall et al. 2011
1b	There is conflicting evidence about the effect of **task-oriented bilateral arm training** to improve performance of activities of daily living when compared to **task-oriented training**.	1	Hsieh et al. 2016
2	**Task-oriented bilateral arm training** when compared to **bilateral arm training with rhythmic auditory cueing** may produce greater improvements in performance of activities of daily living.	1	Song et al. 2015
1b	**Bilateral arm training** may not have a difference in efficacy when compared to **TENS** for improving performance of activities of daily living.	1	Stinear et al. 2014
2	**EMG-triggered NMES with bilateral arm training** may not have a difference in efficacy when compared to **EMG-triggered NMES with unilateral arm training** for improving performance of activities of daily living.	1	Singer et al. 2013
1b	There is conflicting evidence about the effect of **bilateral arm training** to improve performance of activities of daily living when compared to **CIMT**.	2	Brunner et al. 2012; Wu et al. 2011
1b	**Bilateral arm training with rhythmic auditory cueing** may not have a difference in efficacy when compared to **mCIMT** for improving performance of activities of daily living.	1	Van Delden et al. 2013

Key points

The literature is mixed regarding bilateral arm training for upper limb rehabilitation following stroke.

Bilateral arm training may not be beneficial compared to unilateral training for upper limb function.

Bilateral arm training in combination with other therapy approaches may not be beneficial for upper limb rehabilitation.

Strength training

Adopted from: https://www.flintrehab.com/2018/arm-exercises-for-stroke-patients/

Strength training can be defined as an intervention involving repetitive and effortful muscle contractions with the goal of increasing motor unit activity (Ada et al. 2006). The interventions analyzed were classified as either traditional strength training or functional strength training. Traditional strength training involves resistance training in which individual muscles are often isolated and stabilized through protocols involving free weights or machines (Tomljenovic et al. 2011). Functional strength training is based on the principle of specific adaptations to imposed demands (SAID) in which training programs involve tasks that are modeled after common daily activities (Tomljenovic et al. 2011). These tasks often involve multiple muscle groups and require functional movements that are more applicable and may produce gains in strength in performing everyday tasks (Tomljenovic et al. 2011).

18 RCTs were found evaluating strength training for upper extremity motor rehabilitation. Nine RCTs compared strength training to conventional rehabilitation, simple joint mobilization or scapular exercises (Coroian et al. 2018; Dell'Uomo et al. 2017; Kim et al. 2017; Kim and Yim, 2017; Jeon et al. 2016; Da Silva et al. 2015; Lin et al. 2015; Winstein et al. 2004; Trombly et al. 1986). Four RCTs looked at strength training compared to task-specific training (Folkerts et al. 2017; Awad et al. 2015; Thielman et al. 2013; Corti et al. 2012). Three RCTs compared functional strength training to conventional therapy, non-functional strength training or movement performance therapy (Hunter et al. 2018; Park et al. 2017; Graef et al. 2016). Two RCTs looked at functional strength training compared to task-specific training (Agni and Kulkarni, 2017; Pattern et al. 2013).

The methodological details and results of all 18 RCTs are presented in Table 3.

Table 3. RCTs evaluating strength training interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Strength training versus conventional rehabilitation, simple joint mobilization or scapular exercises		
Coroian et al. (2018) RCT (7) N_{Start}=20 N_{End}=16 TPS=Chronic	E: Isokinetic Strengthening C: Passive Joint Mobilization Duration: 45min/d, 3d/wk for 6wk	• Fugl-Meyer Assessment (+con) • Isokinetic Peak Torque (-) • Box and Block Test (-) • Modified Ashworth Scale (-)
Dell'Uomo et al. (2017) RCT (5) N_{Start}=28 N_{End}=28 TPS=Subacute	E: Scapulohumeral Rehabilitation C: Conventional Arm/Trunk Rehabilitation Duration: 20min/d, 5d/wk for 6wk	• Barthel Index (-) • Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-)
Kim et al. (2017) RCT (5) N_{Start}=24 N_{End}=17 TPS=Chronic	E: Scapular Stabilization Exercise C: Simple Scapular Exercise Duration: 30min/d, 3d/wk for 8wk	• Manual Function Test (+exp)
Kim & Yim (2017) RCT (5) N_{Start}=30 N_{End}=29 TPS=Chronic	E: Hand Training and Treadmill Weight Bearing Training C: Conventional Therapy Duration: 30min/d, 3d/wk for 6wk	• Handgrip Strength (-)
Jeon et al. (2016) RCT (5) N_{Start}=12 N_{End}=12 TPS=Chronic	E: Repetitive bilateral and unilateral movements with strength exercises C: Conventional rehabilitation Duration: 30min/d, 3d/wk for 12wk	• Flexion and abduction range of motion (+exp)
Da Silva et al. (2015) RCT (8) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Strength training C: Standard care Duration: 30min/d, 2d/wk for 6wk	• TEMPA (+exp) • Glumerohumeral flexion strength (+exp) • Active shoulder Range of Motion (+exp) • Fugl-Meyer Assessment (+exp)
Lin et al. (2015) RCT (7) N_{Start}=33 N_{End}=33 TPS=Chronic	E: Bilateral Isometric Handgrip Force Training with Visual Feedback C: Routine Therapy Duration: 30min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) • Motor Assessment Scale (+exp) • Barthel Index (+exp)
Winstein et al. (2004) RCT (6) N_{start}=64 N_{end}=44 TPS=Acute	E1: Strength training E2: Functional task practice C: Standard care Duration: 1h/d, 5d/wk for 4wk	E1/E2 vs. C • Fugl Meyer Assessment: (+exp & +exp$_2$) • Functional test of the hemiparetic upper extremity (+exp & +exp$_2$) • Isometric torque (+exp & +exp$_2$)
Trombly et al. (1986) RCT (4) N_{start}=20 N_{end}=20 TPS=Chronic	E1: Resisted Grasp E2: Resisted Extension C: Ballistic Extension Duration: 7d/wk for 3wk	• Finger Extension Range of Motion (-) • Speed and ability to rapidly reverse movement (-)
Strength training versus task-specific training		
Folkerts et al (2017) RCT Crossover (4)	E1: Eccentric Strength Training followed by Task-Oriented Strength Training	• Action Research Arm Test (-) • Shoulder, Elbow and Wrist Strength (-)

N_{Start}=11 N_{End}=10 TPS=Chronic	E2: Task-Oriented Strength Training followed by Eccentric Strength Training Duration: 3d/wk for 4wk	
Awad et al. (2015) RCT (4) N_{Start}=30 N_{End}=23 TPS=Chronic	E: Shoulder Strength Training, Trunk Control Training, and Additional Strengthening Exercises. C: Shoulder Strength Training and Trunk Control Training. Duration: 3d/wk for 6wk	• Shoulder Abduction Peak Torque (+exp) • Shoulder External Rotator Peak Torque (+exp) • Supraspinatus Peak Force (+exp) • Upper Trapezius Peak Force (+exp) • Serratus Anterior Peak Force (+exp) • Scapular Upward Rotation Angle (+exp) • Spinal Lateral Deviation Angle (+exp)
Thielman et al. (2013b) RCT (6) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Progressive resistive strength training C: Task-related training Duration: *Not reported*	• Activate range of motion for shoulder and elbow (+exp) • Wolf Motor Function Test (+exp) • Reaching (+exp)
Corti et al. (2012) RCT Crossover (7) N_{start}=14 N_{end}=14 TPS=Chronic	E1: Power Training E2: Functional Task Practice Duration: 90min/d, 3d/wk for 10wk	• Shoulder Flexion and Elbow Extension (+exp)
Functional strength training versus conventional therapy, strength training or movement performance therapy		
Hunter et al. (2018) RCT (6) N_{Start}=288 N_{End}=240 TPS=Acute	E: Functional Strength Training C: Movement Performance Therapy Duration: 90min/d, 5d/wk for 6wk	• Action Research Arm Test (-) • Wolf Motor Function Test (-) • Grip and Pinch Force (-)
Park et al. (2017) RCT (5) N_{Start}=30 N_{End}=26 TPS=Subacute	E: Boxing C: Conventional Therapy Duration: 30min/d, 3d/wk for 6wk	• Manual Function Test (+exp) • Unaffected Side Hand Grip Strength (+exp)
Graef et al. (2016) RCT (8) N_{Start}=28 N_{End}=27 TPS=Chronic	E: Strength training with a functional goal C: Strength training with non-functional movements Duration: 30min/d, 3d/wk for 5wk	• Upper-Extremity Performance Test (+exp) • Shoulder Strength (-) • Grip Strength (-) • Shoulder Active Range of Motion (-) • Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-)
Functional strength training versus task-specific training		
Agni and Kulkarni (2017) RCT (5) N_{start}=45 N_{end}=37 TPS=Chronic	E1: Strength Training E2: Functional Task-Related Training E3: Functional Task-Related Training with Strength Training Duration: 70min/d, 3d/wk for 6wk	E1 vs. E2: • Chedoke Arm and Hand Inventory (exp_2) • Manual Muscle Strength (+exp) • Fugl-Meyer Assessment (-) E1 vs E3: • Chedoke Arm and Hand Inventory (+exp_3) • Manual Muscle Strength (+exp_3) • Fugl-Meyer Assessment (-) E2 vs E3: • Chedoke Arm and Hand Inventory (-) • Manual Muscle Strength (+exp_3) • Fugl-Meyer Assessment (-)
Patten et al. (2013) USA RCT (7) N_{start}=19 N_{end}=17	E: Functional Task Practice and Power Training C: Functional Task Practice Duration: 75min/d, 3d/wk for 4wk	• Wolf Motor Function Test (-) • Ashworth Scale (-) • Functional Independence Measure (+exp)

TPS=Chronic		

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about strength training

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Strength training** may produce greater improvements in **motor function** than **conventional therapy, simple joint mobilization or scapular exercises**.	6	Coroian et al. 2018; Dell'Uomo et al. 2017; Kim et al. 2017; Da Silva et al. 2015; Lin et al. 2015; Winstein et al. 2004
1b	There is conflicting evidence about the effect of **strength training** to improve **motor function** when compared to **task-specific training**.	3	Agni and Kulkarni, 2017; Folkerts et al. 2017; Thielman et al. 2013
1a	**Functional strength training** may not have a difference in efficacy when compared to **conventional therapy, strength training or movement performance therapy** for improving **motor function**.	4	Hunter et al. 2018; Agni and Kulkarni, 2017; Park et al. 2017; Graef et al. 2016
1b	**Functional strength training** may not have a difference in efficacy when compared to **task-specific training** for improving **motor function**.	2	Agni and Kulkarni, 2017; Pattern et al. 2013

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Strength training** may not have a difference in efficacy when compared to **conventional therapy, simple joint mobilization or scapular exercises** for improving dexterity.	2	Corian et al. 2018; Trombly et al. 1986

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Strength training** may not have a difference in efficacy when compared to **conventional therapy, simple joint mobilization or scapular exercises** for improving spasticity.	2	Coroian et al. 2018; Dell'Uomo et al. 2017
1b	**Functional strength training** may not have a difference in efficacy when compared to **strength training** for improving spasticity.	1	Graef et al. 2016
1b	**Functional strength training** may not have a difference in efficacy when compared to **task-specific training** for improving spasticity.	1	Pattern et al. 2013

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Strength training** may produce greater improvements in range of motion than **conventional therapy, simple joint mobilization or scapular exercises**.	4	Jeon et al. 2016; Da Silva et al. 2015; Winstein et al. 2004; Trombly et al. 1986
1a	**Strength training** may produce greater improvements in range of motion than **task-specific training**.	2	Thielman et al. 2013; Corti et al. 2012

1b	**Functional strength training** may not have a difference in efficacy when compared to **strength training** for improving range of motion.	1	Graef et al. 2016

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **strength training** to improve performance of activities of daily living when compared to **conventional therapy, simple joint mobilization or scapular exercises**.	2	Dell'Uomo et al. 2017; Lin et al. 2015
2	**Functional strength training** may produce greater improvements in performance of activities of daily living than **strength training**.	1	Agni and Kulkarni, 2017
1b	There is conflicting evidence about the effect of **functional strength training** to improve performance of activities of daily living when compared to **task-specific training**.	2	Agni and Kulkarni, 2017; Pattern et al. 2013

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **strength training** to improve muscle strength when compared to **conventional therapy, simple joint mobilization or scapular exercises**.	3	Coroian et al. 2018; Kim and Yim, 2017; Da Silva et al. 2015
2	**Strength training** may produce greater improvements in muscle strength than **task-specific training**.	3	Agni and Kulkarni, 2017; Folkerts et al. 2017; Awad et al. 2015
1a	There is conflicting evidence about the effect of **functional strength training** to improve muscle strength when compared to **conventional therapy, strength training or movement performance therapy**.	4	Hunter et al. 2018; Agni and Kulkarni, 2017; Park et al. 2017; Graef et al. 2016
2	**Functional strength training** may produce greater improvements in muscle strength than **task-specific training**.	1	Agni and Kulkarni, 2017

Key points

The literature is mixed regarding strength training and functional strength training for upper limb rehabilitation following stroke.

Task-specific training

Adopted from: https://www.stltoday.com/lifestyles/health-med-fit/custom-made-rehab-helps-victims-of-stroke/article_06eb5759-3291-5730-930f-725c0d436450.html

Task-specific training involves integrating tasks that are relevant to daily life (e.g. pouring a drink into a cup) into rehabilitation programs, while repetitive task training involves repeated practice of these tasks (Van Peppen et al. 2004; McCombe Waller et al. 2008; Stewart et al. 2006). Usually these consist of motor tasks that are focused on improvement of performance and function through goal-directed practice and repetition (Hubbard et al. 2009). It is well established that task-specific practice is required for motor learning to occur (Schmidt, 1991). Focal transcranial magnetic stimulation and functional magnetic resonance imaging have shown that task-specific training, in comparison to traditional stroke rehabilitation, yields long-lasting cortical reorganization specific to the corresponding areas being used (Classen et al.1998). More specifically, Karni et al. (1995), using functional magnetic resonance imaging, and Classen et al. (1998), using transcranial magnetic stimulation, both reported a slowly evolving, long-term, experience-dependent reorganization of the adult primary motor cortex following daily practice of task-specific motor activities.

Also, of interest is that task-specific sessions (i.e., thumb and hand movements), as short as 15 minutes in duration, are also effective in inducing lasting cortical representational changes (Bütefisch et al.1995; Classen et al.1998). According to Page (2003), intensity alone does not account for the differences between traditional stroke and task-specific rehabilitation. For example, Galea et al. (2001) reported that stroke patients who underwent a 3-week long program consisting of 45-minute task-specific, upper limb training showed improvements in measures of motor function, dexterity, and increased use of the more affected upper limbs. According to Page (2003), other, task-specific, low-intensity regimens designed to improve use and function of the affected limb have also reported significant improvements (Smith et al. 1999; Whitall et al. 2000; Winstein et al. 2001).

A total of 16 RCTs were found that looked task-specific training for upper extremity motor rehabilitation. 12 RCTs looked at task-specific training compared to conventional rehabilitation (Skubik-Peplaski et al. 2017; Brkic et al. 2016; Winstein et al. 2016; Kim et al. 2015; Hubbard et al. 2015; Zondervan et al. 2014; Shimodozono et al. 2013; Thielman et al. 2013; Arya et al. 2012; Thielman et al. 2012; Boyd et al. 2010; Thielman et al. 2004). Two RCTs looked at the intensity of task-specific training delivered (Waddell et al. 2017; Lang et al. 2016). One RCT looked at robotic training with task-specific training compared to robotic training (Hung et al. 2016), and another RCT looked at EMG-triggered NMES with task-specific training compared to EMG-triggered NMES (Kim et al. 2016).

The methodological details and results of all 16 RCTs are presented in Table 4.

Table 4. RCTs evaluating task-specific training for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Task-specific training compared to conventional rehabilitation		
Skubik-Peplaski et al. (2017) RCT (7) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Repetitive Task Practice C: Occupation-Based Intervention Duration: 55min/d, 2d/wk for 4wk	• Fugl-Meyer Assessment (-) • Stroke Impact Scale (-) • Canadian Occupational Performance Measure (-)
Brkic et al. (2016) RCT (5) N_{Start}=24 N_{End}=22 TPS=Acute	E: Repetitive upper limb functional task practice C: Conventional rehabilitation Duration: 7d/wk for 4wk	• Action Research Arm Test (+exp) • Grip Strength (+exp)
Winstein et al. (2016) ICARE Trial RCT (7) N_{Start}=361 N_{End}=361 TPS=Subacute	E1: Structured, task-oriented upper extremity training E2: Dose-equivalent occupational therapy C: Monitoring-only occupational therapy Duration: 1h/d, 3d/wk for 10wk	E1/E2 vs C; E1 vs E2 • Wolf Motor Function Test: (-) E1/E2 vs C; E1 vs E2 • Stroke Impact Scale: (-)
Kim et al. (2015) RCT (8) N_{Start}=44 N_{End}=40 TPS=Chronic	E: Target reach training with visual biofeedback, routine occupational and physical therapy C: Routine occupational and physical therapy Duration: 1h/d, 3d/wk for 4wk	• Fugl-Meyer Upper Extremity (+exp) • Wolf Motor Function Test (+exp) • Reaching speed (+exp) • Range of Motion of the shoulder (+exp) Reach distance (-)
Hubbard et al. (2015) RCT (6) N_{Start}=23 N_{End}=23 TPS=Acute	E: Task-specific training and standard care C: Standard Care Duration: 2h/d, 5d/wk for 3wk	• Upper Limb Motor Assessment Scale (-) • Modified Rankin Scale (-)
Zondervan et al. (2014) RCT (6) N_{Start}=17 N_{End}=16 TPS=Chronic	E: Self-guided, high-repetition home therapy with mechanical arm exerciser C: Conventional therapy Duration: 1h/d, 3d/wk for 3wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-) • Ashworth Scale (-)
Shimodozono et al. (2013) RCT (7) N_{Start}=52 N_{End}=49 TPS=Subacute	E: Repetitive functional exercise C: Conventional rehabilitation Duration: 40min/d, 5d/wk for 4wk	• Action Research Arm Test (+exp) • Grasp and pinch (+exp) • Fugl Meyer (+exp)
Thielman et al. (2013a) RCT (6) N_{start}=37 N_{end}=37 TPS=Chronic	E1: Task-Related Training (TRT) E2: Progressive Resistive Exercises (PRE) Duration: *Not reported*	• Motor Activity Log (+exp) • Wolf Motor Function Test (+exp) • Reaching Performance Scale (+exp) • Fugl-Meyer Assessment (+exp)
Arya et al. (2012) MTST Trial RCT (9) N_{Start}=103 N_{End}=102 TPS=Subacute	E: Task-specific training C: Standard training using the Bobath approach Duration: 1h/d, 4-5d/wk for 4wk	• Fugl Meyer Score (+exp) • Action Research Arm Test (+exp)
Thielman (2012) RCT (6) N_{Start}=16 N_{End}=16	E1: Task-Related Training E2: Resistive Exercise Training Duration: 40-45min/d, 2-3d/wk for 6wk	• Wolf Motor Function Test (-) • Fugl Meyer Assessment (-)

TPS=Chronic		
Boyd et al. (2010) RCT (5) N_{start}=18 N_{end}=18 TPS=Chronic	E: Task-specific training C: General arm training Duration: 3 sessions	• Change in reaction and movement time (+exp)
Thielman et al. (2004) RCT (4) N_{start}=12 N_{end}=12 TPS=Chronic	E: Progressive resistive exercises C: Task-related training Duration: 35min/d, 3d/wk for 4wk	• Modified Ashworth Scale (-) • Rivermead Motor Assessment (-)
Intensity of task-specific training		
Waddell et al. 2017 RCT (5) N_{Start}=85 N_{End}=78 TPS=Chronic	E1: 13.6 hours of task-specific training (100 repetitions/session) E2: 20 hours of task-specific training (200 repetitions/session) E3: 26.3 hours of task-specific training dose group (300 repetitions/session) Duration: 25-50min/d, 4d/wk for 8wk	• Action Research Arm Test (-)
Lang et al. (2016) RCT (5) N_{Start}=85 N_{End}=82 TPS=Chronic	E1: 3200 repetitions of task-specific upper limb training E2: 6400 repetitions of task-specific upper limb training E3: 9600 repetitions of task-specific upper limb training C: Individualized maximum repetitions Duration: 1h/d, 4d/wk for 8wk	• Action Research Arm Test (-) • Stroke Impact Scale (-) • Canadian Occupational Performance Measure (-)
Robotic training with task-specific training		
Hung et al. (2016) RCT (8) N_{Start}=21 N_{End}=21 TPS=Chronic	E: Robotic training + task-specific training C: Robotic training + impairment-oriented training Duration: 20min/d, 3d/wk for 6wk	• Fugl-Meyer Assessment (+exp) • Stroke Impairment Scale (+exp)
EMG-triggered NMES with task-specific training		
Kim et al. (2016) RCT (6) N_{Start}=20 N_{End}=20 TPS=Chronic	E: EMG-triggered NMES with task-oriented training on paretic arm C: EMG-triggered NMES Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp) • Jebsen-Taylor Hand Function Test (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about task-specific training

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Task-specific training** may produce greater improvements in motor function than **conventional therapy**.	11	Skubik-Peplaski et al. 2017; Brkic et al. 2016; Winstein et al. 2016; Kim et al. 2015; Zondervan et al. 2014; Shimodozono et al. 2013; Thielman et al. 2013; Arya et al. 2012; Thielman et al. 2012; Boyd et al. 2010; Thielman et al. 2004
2	**Higher intensity task-specific training** may not have a difference in efficacy when compared to **lower intensity task-specific training** for improving motor function.	2	Waddell et al. 2017; Lang et al. 2016
1b	**Robotic training with task-specific training** may produce greater improvements in motor function than **robotic training with impairment-oriented training**.	1	Hung et al. 2016
1b	**EMG-triggered NMES with task-specific training** may produce greater improvements in motor function than **EMG-triggered NMES alone**.	1	Kim et al. 2016

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**EMG-triggered NMES with task-specific training** may produce greater improvements in dexterity than **EMG-triggered NMES alone**.	1	Kim et al. 2016

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Task-specific training** may produce greater improvements in spasticity than **conventional therapy**.	2	Zondervan et al. 2014; Thielman et al. 2004

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Task-specific training** may produce greater improvements in range of motion than **conventional therapy**.	1	Kim et al. 2016

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Task-specific training** may not have a difference in efficacy when compared to **conventional therapy** for improvements on measures of stroke severity.	1	Hubbard et al. 2015

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Task-specific training** may not have a difference in efficacy when compared to **conventional therapy** for improving performance of activities of daily living.	5	Skubik-Peplaski et al. 2017; Winstein et al. 2016; Hubbard et al. 2015; Zondervan et al. 2014; Thielman et al. 2013
2	**Task-specific training** may produce greater improvements in performance of activities of daily living than **strength training**.	1	Agni and Kulkarni, 2017
2	**Higher intensity task-specific training** may not have a difference in efficacy when compared to **lower intensity task-specific training** for improving performance of activities of daily living.	1	Lang et al. 2016
1b	**Robotic training with task-specific training** may produce greater improvements in performance of activities of daily living than **robotic training with impairment-oriented training**.	1	Hung et al. 2016

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Task-specific training** may produce greater improvements in muscle strength than **conventional therapy**.	2	Brkic et al. 2016; Shimodozono et al. 2013

Key points

Task-specific training, alone or in combination with other therapy approaches, may be beneficial for some aspects of upper limb function following stroke.

Higher and lower intensity task-specific training may have similar effects on upper limb function.

Constraint-Induced Movement Therapy (CIMT)

Adopted from: https://neenahsatellite.com/15429/student-life/creative-writing/magazines/effectiveness-of-cimt/

Roughly 80% of all stroke survivors are left with motor impairments of the upper limb which affects their ability to perform activities of daily living (ADLs) (Kwakkel et al. 2016; Langhorne et al. 2009). Constraint-Induced Movement Therapy (CIMT) is a neurorehabilitation technique originally designed in the 1970s for the purpose of improving upper extremity function post-stroke (Christie et al. 2019; Morris et al. 2006). Traditional CIMT involves three key components: 1) immobilization of the non-paretic hand/arm using a mitt for 90% of waking hours, 2) high intensity task-oriented training with the paretic hand/arm, and 3) behavioural strategies to encourage use of the paretic upper limb after the patient leaves therapy, also known as a transfer package (Etoom et al. 2016).

CIMT is designed to overcome the tendency among hemiparetic patients to avoid the use of their paretic limb, a process termed “learned non-use”. By constraining the non-paretic upper limb, the patient is forced to activate the muscles and neural pathways of their paretic limb, promoting neuroplasticity and use-dependent cortical reorganization (Taub et al. 1999). This form of treatment has shown promise, especially among stroke survivors with moderate upper limb disability. Modified versions of CIMT (mCIMT) have since been developed with varied dosage, timing, and composition of therapy but generally include less intense training of the paretic limb over a longer period of time (Kwakkel et al. 2016). CIMT is often compared to “forced use”, or constraint only treatments, which are conceptually simpler versions of CIMT that do not apply operant training techniques.

Here we provide a review of 54 published RCTs related to CIMT for upper extremity motor rehabilitation. In order to better contextualize this body of evidence, studies were separated and classified according to the type of treatment (CIMT or mCIMT) as well as the time poststroke (acute/subacute phase (<6 months) or chronic stage (>6 months)), leading to 4 groups of RCTs. The authors' own declaration of the type of therapy (i.e. mCIMT or CIMT) was used for classification purposes.

The first two tables (Table 5, Table 6) list the summary of 12 RCTs examining CIMT in the acute/subacute phase (Seok et al. 2016; Shah et al. 2016; Song et al. 2016; Batool et al. 2015;

Thrane et al. 2015; Yoon et al. 2014; Dromerick et al. 2009; Boake et al. 2007; Ro et al. 2006; Page et al. 2005; Plougman and Corbett 2004; Dromerick et al. 2000) and 22 RCTs evaluating CIMT in the chronic phase (Souza et al. 2015; Nadeau et al. 2014; Takebayshi et al. 2013; Huseyinsinoglu et al. 2012; Khan et al. 2011; Wu et al. 2011; Lin et al. 2010; Wolf et al. 2010; Lin et al. 2009; Dahl et al. 2008; Lin et al. 2008; Sawaki et al. 2008; Wolf et al. 2008; Lin et al. 2007; Wu et al. 2007; Brogardh and Bengt, 2006; Richards et al. 2006; Underwood et al. 2006; Wolf et al. 2006; Alberts et al. 2004; Suputtitada et al. 2004; Wittenberg et al. 2003) poststroke.

The last two tables (Table 7, Table 8) list the summary of 7 RCTs examining mCIMT in the acute/subacute phase (Kwakkel et al. 2016; Liu et al. 2016; El-Helow et al. 2014; Treger et al. 2012; Brogardh et al. 2009; Hammer and Lindmark, 2009; Myint et al. 2007) and 13 RCTs in the chronic phase (Doussoulin et al. 2017; Hsieh et al. 2016; Yadav et al. 2016; Barzel et al. 2015; Smania et al. 2012; Wang et al. 2011; Hayner et al. 2010; Page et al. 2008; Lin et al. 2007; Wu et al. 2007b; Wu et al. 2007c; Page et al. 2004; Page et al. 2002).

Table 5. Summary of RCTs Evaluating CIMT in the acute/subacute (<6months) phase for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Shah et al. (2016a) RCT (5) N_{Start}=45 N_{End}=40 TPS=Subacute	E: CIMT C: Motor Relearning Program Duration: 80% of working hours	• Motor Activity Log (+exp) • Nine Hole Peg Test (-) • Fugl-Meyer Assessment (-)
Song et al. (2016a) RCT (5) N_{Start}=30 N_{End}=30 TPS=Acute	E: Scalp cluster acupuncture and Constraint Induced Movement Therapy C: Body acupuncture and traditional rehabilitation therapy Duration: 5-6h, 6d/wk for 2wk	• Fugl-Meyer Assessment (-)
Batool et al. (2015) RCT (5) N_{Start}=42 N_{End}=42 TPS=Subacute	E: CIMT C: Motor Relearning Programme Duration: 2h, 6d/wk for 3wk	• Modified Ashworth Scale (+exp) • Functional Independence Measure (+exp)
Thrane et al. (2015) RCT (7) N_{Start}=47 N_{End}=47 TPS=Acute	E: CIMT C: Usual Care Duration: 3h, 1/d for 10d	• Wolf Motor Function Test (-) • Stroke Impact Scale (-) • Fugl-Meyer Assessment (-)
Boake et al. (2007) RCT (5) N_{start}=23 N_{end}=16 TPS=Acute	E: CIMT C: Traditional rehabilitation Duration: 3h, 6d/wk for 2wk	• Fugl Meyer Motor recovery (-) • Grooved Pegboard test (-) • Motor Activity Log: Quality of Movement (+exp)
Ro et al. (2006) RCT (6) N_{start}=8 N_{end}=8 TPS=Acute	E: CIMT C: Traditional rehabilitation Duration: 3h, 6d/wk for 2wk	• Grooved Pegboard test (+exp) • Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp)
Page et al. (2005b) RCT (5) N_{start}=10 N_{end}=10 TPS=Subacute	E: CIMT C: Regular rehabilitation Duration: 30min, 3d/wk for 10wk	• Action Research Arm Test (-) • Fugl-Meyer Assessment (-) • Motor Activity Log (-)
Ploughman & Corbett (2004) RCT (5) N_{start}=23 N_{end}=23 TPS=Subacute	E: Forced Use Therapy (Constraint without Shaping) C: Conventional Therapy Duration: 1-6h (incremental increase), 5d/wk for 2wk	• Chedoke McMaster Impairment Inventory (-) • Action Research Arm Test (-) • Functional Independence Measure (-)
Dromerick et al. (2000) RCT (6) N_{start}=23 N_{end}=20 TPS=Acute	E: CIMT C: Traditional upper extremity therapy Duration: 2h, 5d/wk for 2wk	• Action Research Arm Test (+exp) • Functional Independence Measure (-) • Barthel Index (-)
High Intensity CIMT compared to CIMT		
VECTORS (Study Acronym) Dromerick et al. (2009) RCT (6) N_{start}=52 N_{end}=52	E1: High-intensity CIMT E2: Standard CIMT C: ADL and UE bilateral training Exercises Duration: 2-3h, 5d/wk for 2wk	E2/C vs E1 • Action Research Arm Test: (+exp$_2$, +con) • Functional Independence Measure (-) • Stroke Impact Scale (-)

TPS=Subacute		
CIMT combined with another intervention		
Seok et al. (2016) RCT (5) N_{Start}=32 N_{End}=30 TPS=Subacute	E1: CIMT with Visual Biofeedback E2: Visual Biofeedback C: Conventional Occupational Therapy Duration: 1h, 5d/wk for 2wk	E1 vs C • Grasp Strength (+exp) • Pinch Strength (+exp) • Wolf Motor Function Test (+exp) • Fugl-Meyer Assessment (+exp) E2 vs C • Grasp Strength (-) • Pinch Strength (-) • Wolf Motor Function Test (+exp_2) • Fugl-Meyer Assessment (+exp_2)
Yoon et al. (2014) RCT (7) N_{Start}=26 N_{End}=26 TPS=Subacute	E1: CIMT combined with mirror therapy E2: CIMT C: Conventional therapy Duration: 6h, 5d/wk for 2wk	E1 v E2 • Box and block test (+exp) • Nine-hole pegboard test (+exp) • Grip strength (+exp) • Brunnstrom Recovery Stages (-) • Wolf motor function test (-) • Fugl-Meyer Assessment (-) • Korean Modified Barthel Index (-) E1 v C • Box and block test (+exp) • Nine-hole pegboard test (+exp) • Grip strength (+exp) • Brunnstrom Recovery Stages (-) • Wolf motor function test (+exp) • Fugl-Meyer Assessment (-) • Korean Modified Barthel Index (+exp) E2 vs C • Box and block test (+exp_2) • Nine-hole pegboard test (-) • Grip strength (+exp_2) • Brunnstrom Recovery Stages (-) • Wolf motor function test (+exp_2) • Fugl-Meyer Assessment (-) • Korean Modified Barthel Index (+exp_2)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Table 6. Summary of RCTs evaluating CIMT in the chronic (>6months) phase poststroke for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Huseyinsinoglu et al. (2012) RCT (6) N_{start}=24 N_{end}=21 TPS=Chronic	E: CIMT C: Bobath Duration: 3h/d for 10d	• Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Functional Independence Measure (-)
Khan et al. (2011) RCT (6) N_{start}=44 N_{end}=39 TPS=Chronic	E1: CIMT E2: Therapeutic Climbing C: Conventional Neurological Therapy Duration: 15-20h/wk for 4wk	E1 vs E2 • Wolf Motor Function Test (+exp) • Motor Activity Log (-) • Isometric Strength (-) • Active Range of Motion (-) E1 vs C • Wolf Motor Function Test (-) • Motor Activity Log (-) • Isometric Strength (-) • Active Range of Motion (-)
Wu et al. (2011) RCT (5) N_{start}=66 N_{end}=65 TPS=Chronic	E1: Distributed CIMT E2: Bilateral Arm Training C: Routine Therapy Duration: 2h, 5d/wk for 3wk	E1/E2 vs C • Unilateral and Bilateral Smoothness while Reaching: (+exp, +exp$_2$) E1 vs E2/C • Motor Activity Log: (+exp) E1 vs E2/C • Wolf Motor Function Test: (+exp)
Lin et al. (2010) RCT (5) N_{start}=13 N_{end}=13 TPS=Chronic	E: Distributed CIMT C: Routine Therapy Duration: 2h, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp)
Lin et al. (2009a) RCT (5) N_{start}=32 N_{end}=32 TPS=Chronic	E: CIMT C: Dose Matched Control Intervention Duration: 2h, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Stroke Impact Scale (+exp) • Nottingham Extended Activities of Daily Living (+exp) • Motor Activity Log (+exp)
Dahl et al. (2008) RCT (8) N_{start}=30 N_{end}=30 TPS=Chronic	E: CIMT C: Community-based rehabilitation Duration: 6h, 5d/wk for 2wk	• Wolf Motor Function Test: post (+exp), 6mo (-) • Motor Activity Log (-) • Functional Independence Measure (-) • Stroke Impact Scale (-)
Lin et al. (2008) RCT (5) N_{start}=22 N_{end}=22 TPS=Chronic	E: CIMT C: Traditional Intervention Duration: 2h, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp) • Motor Activity Log (-) • Nottingham Extended Activities of Daily Living Scale (-), mobility subsection (+exp)
Lin et al. (2007) RCT (5) N_{start}=35 N_{end}=32 TPS=Chronic	E: CIMT C: Traditional therapy (neurodevelopmental) Duration: 2h, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp) • Motor Activity Log (-)
Wu et al. (2007a) RCT (6)	E: CIMT C: Regular interdisciplinary rehab	• Motor Activity Log (+exp) • Fugl-Meyer Assessment (-)

N_{start}=47 N_{end}=47 TPS=Chronic	Duration: 2h, 5d/wk for 3wk	
Underwood et al. (2006) RCT (8) N_{start}=41 N_{end}=32 TPS=Chronic	E: CIMT + shaping procedure C: Usual care Duration: 6h, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-)
Wolf et al. (2006) RCT (8) EXCITE N_{start}=222 N_{end}=201 TPS=Chronic	E: CIMT + shaping procedure C: Usual care Duration: 6h, 5d/wk for 2wk	• Wolf Motor Function Test (+exp) • Motor Activity Log (+exp)
Alberts et al. (2004) RCT (6) N_{start}=10 N_{end}=10 TPS=Subacute	E: CIMT C: Conventional rehabilitation Duration: 6h, 5d/wk for 2wk	• Maximum precision grip (+exp) • Wolf Motor Function Test (+exp)
Suputtitada et al. (2004) RCT (6) N_{start}=69 N_{end}=69 TPS=Chronic	E: CIMT C: Bimanual-upper-extremity training based on NDT approach Duration: 6h, 5d/wk for 2wk	• Action Research Arm Test (+exp) • Pinch test (+exp)
High compared to low intensity CIMT		
Souza et al. (2015) RCT (5) N_{start}=24 N_{end}=19 TPS=Chronic	E1: CIMT high intensity (3h) E2: CIMT low intensity (1h) Duration: 1/3h, 3-4d/wk for 4wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-)
Brogårdh & Bengt (2006) RCT (7) N_{start}=16 N_{end}=16 TPS=Chronic	E: CIMT and using mitt at home for another 3 months every other day C: CIMT Duration: 6h, 5d/wk for 2wk	• Modified Motor Assessment Scale (-) • Sollerman Hand Function Test (-) • Motor Activity Log (-)
Wittenberg et al. (2003) RCT (5) N_{start}=16 N_{end}=16 TPS=Chronic	E: Intense CIMT (6h) C: Less intense CIMT (3h) Duration: 3/6h/d for 10d	• Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Assessment of Motor and Process Skills (-)
High intensity CIMT compared to low intensity CIMT combined with cyloserine (antibiotic)		
Nadeau et al. (2014) RCT (7) N_{Start}=24 N_{End}=22 TPS=Chronic	E1: CIMT-6hr + cycloserine C1: CIMT-6hr + placebo E2: CIMT-2hr + cycloserine C2: CIMT-2hr + placebo Duration: 2/6h, 3-5d/wk for 10wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-) • Motor Activity Log (-)
Early compared to delayed CIMT		
Wolf et al. (2010) RCT (8) N_{start}=226 N_{end}=192 TPS=Chronic	E1: CIMT early (3-9 months' post stroke) E2: CIMT delayed (15 to 21 months post stroke) Duration: 90% of waking time for 2wk	• Wolf Motor Function Test (+exp) • Motor Activity Log (+exp) • Stroke Impact Scale (+exp)
Sawaki et al. (2008) RCT (8) N_{start}=30 N_{end}=30 TPS=Chronic	E: Early CIMT C: Delayed CIMT (4mo after randomization) Duration: 90% of d for 2wk	• Grip strength (+exp) • Wolf Motor Function Test (-)
Wolf et al. (2008)	E1: CIMT early (3-9 months' post stroke)	• Wolf Motor Function Test (+exp)

RCT (8) N_{start}=98 N_{end}=70 TPS=Chronic	E2: CIMT delayed (15 to 21 months post stroke) Duration: 90% of waking time for 2wk	• Motor Activity Log (+exp) • Functional Independence Measure (+exp) • Stroke Impact Scale (+exp)
CIMT with transfer package		
Takebayashi et al. (2013) RCT (5) N_{Start}=23 N_{End}=21 TPS=Chronic	E: CIMT + transfer package (train affected arm) C: CIMT Duration: 4.5h spread over 2wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (+exp)
Taub et al. (2013) RCT (5) N_{Start}=45 N_{End}=40 TPS=Chronic	E1: Shaping training + CIMT transfer package (TP) E2: Repetitive task practice + TP E3: Repetitive task practice C: Shaping training	E1/E2 vs. E3/C • Motor Activity Log (+exp, +exp_2) E1/E2 vs. E3/C • Wolf Motor Function Test (+exp, +exp_2)
CIMT combined with rTMS or donepezil (cholinesterase inhibitor)		
Richards et al. (2006) Secondary analyses of two parallel RCTs (7) N_{start}=39 N_{end}=35 TPS=Chronic	E1: Traditional CIMT (6h) + donepezil C1: Traditional CIMT (6h) + placebo E2: Shortened CIMT (1h) + repetitive transcranial magnetic stimulation (rTMS) C2: Shortened CIMT (1h) + sham rTMS Duration:1/6h, 5d/wk for 2wk	E1 vs C1 • Motor Activity Log (+exp) • Wolf Motor Function Test: (-) E2 vs C2 • Motor Activity Log (-) • Wolf Motor Function Test: (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Table 7. Summary of RCTs Evaluating Modified CIMT in the acute/Subacute (<6 months) phase for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Kwakkel et al. (2016) RCT (7) N_{Start}=159 N_{End}=159 TPS=Subacute	E1: Electromyographic Neuromuscular Stimulation on finger extensors E2: Modified Constraint Induced Movement Therapy C1: Unfavourable prognosis based on voluntary finger extension. Received usual care. C2: Favourable prognosis based on voluntary finger extension. Received usual care. Duration: 3h, 5d/wk for 3wk	E2 vs C2; E1 vs C1 • Action Research Arm Test: (+exp$_2$) • Fugl-Meyer Assessment: (-) • Wolf Motor Function Test (-) • Motricity Index (-) • Erasmus Modified Nottingham Sensory Assessment (-) • Nine-Hole Peg Test (-) • Frenchay Arm Test (-) • Motor Activity Log (-) • Stroke Impact Scale-Hand (+exp$_2$)
Liu et al. (2016) RCT (6) N_{Start}=90 N_{End}=86 TPS=Subacute	E1: Modified Constraint Induced Movement Therapy E2: Self-Regulated Modified Constraint Induced Movement Therapy C: Conventional Therapy Duration: 1h, 5d/wk for 2wk	E1 vs C • Action Research Arm Test (+exp) • Fugl-Meyer Assessment (+exp) • Lawton Instrumental Activities of Daily Living (+exp) • Motor Activity Log (+exp) E2 vs C • Action Research Arm Test (+exp$_2$) • Fugl-Meyer Assessment (+exp$_2$) • Lawton Instrumental Activities of Daily Living (-) • Motor Activity Log (+exp$_2$) E1 vs E2 • Action Research Arm Test (-) • Fugl-Meyer Assessment (+exp$_2$) • Lawton Instrumental Activities of Daily Living (+exp$_2$) • Motor Activity Log (+exp$_2$)
El-Helow et al. (2014) RCT (6) N_{start}=60 N_{end}=60 TPS=Acute	E: Modified Constraint Induced Movement Therapy C: Conventional Rehabilitation Duration: 6h/d for 2wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp)
Treger et al. (2012) RCT (7) N_{start}=28 N_{end}=28 TPS=Subacute	E: mCIMT C: Traditional rehabilitation Duration: 4h, 2d/wk for 2wk	• Functional Independence Measure (-) • Manual Function Test (-)
Brogårdh et al. (2009) RCT (5) N_{start}=24 N_{end}=24 TPS=Subacute	E: Shortened CIMT (mitt use) C: No mitt use Duration: 90% of waking time for 12d	• Motor Assessment Scale (-) • Sollerman Hand Function Tst (-) • 2-Point Discrimination Test (-) • Motor Activity Log Test (-)

Hammer & Lindmark (2009) RCT (6) N_{Start}=30 N_{End}=26 TPS=Subacute	E: Restraining sling and Standard Rehabilitation C: Standard Rehabilitation Duration: 6h, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Motor Assessment Scale (-) • 16-Hole Peg Test (-) • Grip strength ratio (-) • Modified Ashworth Scale (-)
Myint et al. (2007) RCT (7) N_{start}=43 N_{end}=43 TPS=Subacute	E: mCIMT C: Traditional rehabilitation Duration: 4h/d for 10d	• Action Research Arm Test (+exp) • Motor Activity Log (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Table 8. Summary of RCTs Evaluating Modified CIMT in the Chronic (>6 months) phase for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Hsieh et al. (2016) RCT (7) N_{start}=34 N_{end}=34 TPS=Chronic	E: mCIMT C: Regular Therapy Duration: 105min, 5d/wk for 4wk	• Wolf Motor Function Test (+exp) • Nottingham Extended Activities of Daily Living (+exp) • Functional Independence Measure (-)
Yadav et al. (2016) RCT (5) N_{start}=65 N_{end}=60 TPS=Chronic	E: mCIMT C: Conventional rehabilitation Duration: 3h, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp)
Barzel et al. (2015) RCT (6) N_{start}=156 N_{end}=156 TPS=Chronic	E: Home CIMT C: Standard Therapy Duration: 5h/wk for 4wk	• Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Nine Hole Peg Test (-) • Stroke Impact Scale (-) • Barthel Index (-) • Instrumental Activities of Daily Living (-)
Smania et al. (2012) RCT (8) N_{start}=66 N_{end}=40 TPS=Chronic	E: mCIMT C: Dose-match task-specific therapy Duration: 2h, 5d/wk for 2wk	• Wolf Motor Function Test (+exp) • Motor Activity Log (+exp)
Wang et al. (2011) RCT (4) N_{start}=30 N_{end}=30 TPS=Chronic	E1: mCIMT E2: Intensive conventional therapy C: Conventional therapy Duration: 3h, 5d/wk for 4wk	• Wolf Motor Function Test (+exp)
Hayner et al. (2010) RCT (4) N_{start}=12 N_{end}=12 TPS=Chronic	E: mCIMT C: Bilateral training Duration: 6h/d for 10d	• Wolf Motor Function Test (-) • COPM (-)
Page et al. (2008) RCT (5) N_{start}=35 N_{end}=35 TPS=Chronic	E1: mCIMT + physical and occupational therapy E2: Traditional rehab C: No therapy Duration: 5h, 5d/wk for 10wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (+exp)
Lin et al. (2007) RCT (7) N_{start}=34 N_{end}=31 TPS=Chronic	E: mCIMT C: Traditional rehab Duration: 6h, 5d/wk for 3wk	• Motor Activity Log (+exp) • Functional Independence Measure (+exp)
Wu et al. (2007b) RCT (5) N_{start}=26 N_{end}=26 TPS=Chronic	E: mCIMT + a restraining mitt on the unaffected hand C: Traditional therapy Duration: 2h, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp) • Motor Activity Log (+exp) • Stroke Impact Scale (+exp)
Wu et al. (2007c) RCT (6) N_{start}=30	E: mCIMT C: Regular occupational therapy Duration: 2h, 5d/wk for 3wk	• Motor Activity Log (+exp) • Functional Independence Measure (+exp)

N_{end}=30 TPS=Chronic		
Page et al. (2004) RCT (6) N_{start}=17 N_{end}=17 TPS=Chronic	E: mCIMT C1: Traditional Rehabilitation C2: No Therapy Duration: 5h, 5d/wk for 10wk	E vs C1: • Fugl-Meyer Assessment (+exp) • Action Research Arm Test (-) E1 vs C2: • Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp) C1 vs C2: • Fugl-Meyer Assessment (-) • Action Research Arm Test (+con_1) •
Page et al. (2002) RCT (5) N_{start}=14 N_{end}=14 TPS=Chronic	E1: mCIMT + physical and occupational therapy E2: Traditional rehab C: No therapy Duration: 30min, 3d/wk for 10wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp)
mCIMT in group or individual setting		
Doussoulin et al. (2017) RCT (5) N_{Start}=36 N_{End}=36 TPS=Chronic	E1: mCIMT group therapy E2: mCIMT individual therapy Duration: 3h/d for 10d	• Motor Activity Log (+exp) • Action Research Arm Test (+exp) • Functional Independence Measure (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about CIMT and mCIMT

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**CIMT** may not have a difference in efficacy when compared to **conventional therapy or motor relearning programmes** for improving motor function during the acute/subacute phase poststroke.	8	Shah et al. 2016; Song et al. 2016; Thrane et al. 2015; Yoon et al. 2014; Dromerick et al. 2009; Boake et al. 2007; Page et al. 2005; Plougman and Corbett 2004; Dromerick et al. 2000
2	**CIMT combined with visual biofeedback** may produce greater improvements in motor function than **conventional therapy** on its own during the acute/subacute phase poststroke.	1	Seok et al. 2016
1b	**CIMT combined with mirror therapy** may not have a difference in efficacy when compared to **CIMT on its own** for improving motor function during the acute/subacute phase poststroke.	1	Yoon et al. 2014
1a	**CIMT** may produce greater improvements in motor function than **conventional therapy or neurodevelopmental techniques** during the chronic phase poststroke.	13	Huseyinsinoglu et al. 2012; Khan et al. 2011; Wu et al. 2011; Lin et al. 2010; Lin et al. 2009; Dahl et al. 2008; Lin et al. 2008; Lin et al. 2007; Wu et al. 2007; Underwood et al. 2006; Wolf et al. 2006; Alberts et al. 2004; Suputtitada et al. 2004
1b	**High intensity CIMT** may not have a difference in efficacy when compared to **low intensity CIMT** on its own for improving motor function during the chronic phase poststroke.	3	Souza et al. 2015; Brogardh and Bengt, 2006; Wittenberg et al. 2003
1b	**High intensity CIMT with/without cycloserine** may not have a difference in efficacy when compared to **low intensity CIMT with/without cycloserine** for improving motor function during the chronic phase poststroke.	1	Nadeau et al. 2014
1a	**Early CIMT** may produce greater improvements in motor function than **delayed CIMT** during the chronic phase poststroke.	3	Wolf et al. 2010; Sawaki et al. 2008; Wolf et al. 2008
2	There is conflicting evidence about the of **CIMT with the transfer package protocol** when compared to **traditional CIMT** for improving motor function during the chronic phase poststroke.	2	Takebayashi et al. 2013; Taub et al. 2013
1a	There is conflicting evidence about the effect of **mCIMT** to improve motor function when compared to **conventional therapy or bilateral arm training** during the acute/subacute phase poststroke.	7	Kwakkel et al. 2016; Liu et al. 2016; El-Helow et al. 2014; Treger et al. 2012; Brogardh et al. 2009; Hammer and Lindmark, 2009; Myint et al. 2007
1a	**mCIMT** may produce greater improvements in motor function than **conventional therapy or bilateral arm training** during the chronic phase poststroke.	10	Hsieh et al. 2016; Yadav et al. 2016; Barzel et al. 2015; Smania et al. 2012; Wang et al. 2011; Hayner et al. 2010; Page et al. 2008; Wu et al. 2007b; Page et al. 2004; Page et al. 2002
2	**Group based mCIMT** may produce greater improvements in motor function than **one on one mCIMT sessions** during the chronic phase poststroke.	1	Doussoulin et al. 2017

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **CIMT** to improve dexterity when compared to **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	4	Shah et al. 2016; Yoon et al. 2014; Boake et al. 2007; Ro et al. 2006
1b	**CIMT combined with mirror therapy** may produce greater improvements in dexterity than **CIMT on its own** during the acute/subacute phase poststroke.	1	Yoon et al. 2014
1b	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving dexterity during the acute/subacute phase poststroke.	1	Kwakkel et al. 2016
1b	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving dexterity during the chronic phase poststroke.	1	Barzel et al. 2015

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**CIMT** may produce greater improvements in spasticity than **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	1	Batool et al. 2015
1b	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving spasticity during the acute/subacute phase poststroke.	1	Hammer and Lindmark, 2009

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**CIMT** not have a difference in efficacy when compared to **conventional therapy or neurodevelopmental techniques** for improving range of motion during the chronic phase poststroke.	1	Khan et al. 2011

PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving proprioception during the acute/subacute phase poststroke.	2	Kwakkel et al. 2016; Brogardh et al. 2009

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**CIMT** may produce greater improvements in muscle strength than **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	1	Yoon et al. 2014
2	**CIMT combined with visual biofeedback** may produce greater improvements in muscle strength than **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	1	Seok et al. 2016
1b	**CIMT combined with mirror therapy** may produce greater improvements in muscle strength than **CIMT on its own** during the acute/subacute phase poststroke.	1	Yoon et al. 2014
1a	**CIMT** may produce greater improvements in muscle strength than **conventional therapy or neurodevelopmental techniques** during the chronic phase poststroke.	2	Alberts et al. 2004; Suputtitada et al. 2004
1b	**Early CIMT** may produce greater improvements in muscle strength than **delayed CIMT** during the chronic phase poststroke.	1	Sawaki et al. 2008
1a	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving muscle strength during the acute/subacute phase poststroke.	2	Kwakkel et al. 2016; Hammer and Lindmark, 2009

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **CIMT** to improve performance of activities of daily living when compared to **conventional therapy or motor relearning programmes** during the acute/subacute phase poststroke.	8	Shah et al. 2016; Batool et al. 2015; Thrane et al. 2015; Yoon et al. 2014; Boake et al. 2007; Ro et al. 2006; Page et al. 2005; Dromerick et al. 2000
1b	**CIMT combined with mirror therapy** may not have a difference in efficacy when compared to **CIMT on its own** for improving performance of activities of daily living during the acute/subacute phase poststroke.	1	Yoon et al. 2014
1a	**CIMT** may produce greater improvements in performance of activities of daily living than **conventional therapy or neurodevelopmental techniques** during the chronic phase poststroke.	10	Huseyinsinoglu et al. 2012; Khan et al. 2011; Wu et al. 2011; Lin et al. 2010; Lin et al. 2009; Dahl et al. 2008; Lin et al. 2008; Lin et al. 2007; Wu et al. 2007; Wolf et al. 2006
1b	**High intensity CIMT** may not have a difference in efficacy when compared to **low intensity CIMT** on its	3	Souza et al. 2015; Brogardh and Bengt, 2006; Wittenberg et al. 2003

	own for improving performance of activities of daily living during the chronic phase poststroke.		
1b	**High intensity CIMT with/without cycloserine** may not have a difference in efficacy when compared to **low intensity CIMT with/without cycloserine** for improving performance of activities of daily living during the chronic phase poststroke.	1	Nadeau et al. 2014
1a	**Early CIMT** may produce greater improvements in performance of activities of daily living than **delayed CIMT** during the chronic phase poststroke.	2	Wolf et al. 2010; Wolf et al. 2008
2	**CIMT with the transfer package protocol** may not have a difference in efficacy when compared to **traditional CIMT** for performance of activities of daily living during the chronic phase poststroke.	1	Takebayashi et al. 2013
1a	**mCIMT** not have a difference in efficacy when compared to **conventional therapy or bilateral arm training** for improving performance of activities of daily living during the acute/subacute phase poststroke.	6	Kwakkel et al. 2016; Liu et al. 2016; Treger et al. 2012; Brogardh et al. 2009; Hammer and Lindmark, 2009; Myint et al. 2007
1a	**mCIMT** may produce greater improvements in performance of activities of daily living than **conventional therapy or bilateral arm training** during the chronic phase poststroke.	8	Hsieh et al. 2016; Yadav et al. 2016; Barzel et al. 2015; Smania et al. 2012; Hayner et al. 2010; Lin et al. 2007; Wu et al. 2007b; Wu et al. 2007c
2	**Group based mCIMT** may produce greater improvements in performance of activities of daily living than **one on one mCIMT sessions** during the chronic phase poststroke.	1	Doussoulin et al. 2017

Key points

Constraint-induced movement therapy may be beneficial for upper limb rehabilitation in the chronic phase following stroke.

The literature is mixed regarding constraint-induced movement therapy for upper limb rehabilitation in the subacute/acute phase following stroke.

Modified constraint-induced movement therapy may be beneficial for upper limb rehabilitation in the chronic phase following stroke.

Modified constraint-induced movement therapy may not be beneficial for upper limb rehabilitation in the subacute/acute phase following stroke.

Higher and lower intensity constraint-induced movement therapy may have similar effects on upper limb function in the chronic phase following stroke.

The literature is mixed regarding constraint-induced movement therapy in combination with other therapy approaches for upper limb rehabilitation following stoke.

Trunk restraint

Adopted from: https://www.ortopedia-almirall.com/en/producto/cinturon-sujecion-tronco-y-pelvis-cierre-magnetico/

Reaching movements performed with the affected arm poststroke are often accompanied by compensatory trunk or shoulder girdle movements, which overextend the reach of the arm (Michaelsen et al. 2001). Restriction of compensatory trunk movements may encourage recovery of “normal” reaching patterns in the hemiparetic arm when reaching for objects placed within arm’s length (Michaelsen & Levin, 2004). Eight RCTs (Bang et al. 2015; Lima et al. 2014; Wu et al. 2012a; Wu et al. 2012b; Thielman et al. 2010; Woodbury et al. 2009; Michaelsen et al. 2006; Michaelsen and Levin, 2004) have evaluated the effectiveness of trunk restraint combined with other training to improve the movement quality of reaching tasks. Their methodological details and results are presented in Table 9.

Table 9. RCTs evaluating trunk restraint training for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
mCIMT + trunk restraint training		
Bang et al. (2015) RCT (9) N_{Start}=18 N_{End}=18 TPS=Subacute	E: mCIMT + trunk resistant training C: mCIMT Duration: 30 min, 5 d/wk, for 4 wk	• Action Research Arm Test (+exp) • Fugl-Meyer Assessment (+exp) • Modified Barthel Index (+exp) • Motor Activity Log (+exp)
Lima et al. (2014) RCT (8) N_{Start}=22 N_{End}=15 TPS=Chronic	E: mCIMT + trunk resistant training C: mCIMT Duration: *Not Reported*	• Motor Activity Log (-) • Bilateral Activity Assessment Scale (-) • Wolf Motor Function Test (-) • Global strength (-)
Woodbury et al. (2009) RCT (5) N_{start}=11 N_{end}=11 TPS=Chronic	E: mCIMT + trunk restraint C: mCIMT Duration: 6 hr, 5d/wk for 2 wk	• Hand path trajectories (+exp)
Distributed CIT + trunk restraint training		
Wu et al. (2012a) RCT (5) N_{start}=57 N_{end}=57 TPS=Chronic	E1: Distributed constraint-induced therapy (dCIT) + trunk restraint E2: dCIT C: Usual care (neurodevelopmental treatment techniques) Duration: 2hr, 5d/wk for 3 wk	E1/E2 vs. C • Action Research Arm Test (+exp, exp_2) • Frenchay Activities Index (+exp, exp_2) • Motor Activity Log (+exp, exp_2) • Stroke Impact Scale (+exp, exp_2)
Wu et al. (2012b) RCT (5) N_{start}=45 N_{end}=45 TPS=Chronic	E1: Distributed constraint-induced therapy (dCIT) + trunk restraint E2: dCIT C: Dose-matched control intervention (neurodevelopmental treatment techniques) Duration: 2hr, 3d/wk for 3 wk	E1/E2 vs. C • Motor Activity Log (+exp, +exp_2) • Fugl-Meyer Assessment (+exp)
Auditory feedback		
Thielman (2010) RCT (4) N_{start}=16 N_{end}=16 TPS=Chronic	E: Auditory feedback about trunk position C: Trunk restraint with external device Duration: 45 min, 3d/wk for 4 wk	• Reaching Performance Scale Near Target (+exp) • Reaching Performance Scale Far Target (-)
Reach to grasp training with trunk restraint		
Michaelsen el al. (2006) RCT (7) N_{Start}=30 N_{End}=10 TPS=Chronic	E: Object-related reach-to-grasp training + trunk restraint C: Unrestrained reach-to-grasp training Duration: 40 min, 3d/wk for 5 wk	• Upper Extremity Performance Test (+exp) • Fugl-Meyer Assessment (+exp) • Box and Block Test (-)
Michaelsen & Levin (2004) RCT (5) N_{start}=28 N_{end}=28 TPS=Chronic	E: Reach-to-grasp training + trunk restraint C: Unrestrained reach-to-grasp training Duration: 60 sessions over 8 weeks	• Shoulder horizontal adduction (-) • Shoulder flexion (-) • Elbow Extension (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about trunk restraint training

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **trunk restraint combined with mCIMT** to improve motor function when compared to **mCIMT**.	3	Bang et al. 2015; Lima et al. 2014; Woodbury et al. 2009
2	**Trunk restraint combined with distributed CIT** may produce greater improvements in motor function than **conventional rehabilitation**.	2	Wu et al. 2012a; Wu et al. 2012b
2	There is conflicting evidence about the effect of **auditory feedback regarding trunk position** to improve motor function when compared to **trunk restraint training**.	1	Thielman 2010
1b	**Trunk restraint combined with reaching training** may produce greater improvements in motor function than **reaching training alone**.	2	Michaelsen & Levin 2004; Michaelsen et al. 2006

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Trunk restraint combined with reaching training** compared to **reaching training alone** may not have a difference in efficacy for dexterity.	1	Michaelsen et al. 2006

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **trunk restraint combined with mCIMT** to improve performance of activities of daily living when compared to **mCIMT**.	3	Bang et al. 2015; Lima et al. 2014; Woodbury et al. 2009
2	**Trunk restraint combined with distributed CIMT** may produce greater improvements in performance of activities of daily living than **conventional rehabilitation**.	2	Wu et al. 2012a; Wu et al. 2012b

Key points

Trunk restraint with reaching training or distributed constraint induced therapy may improve some aspects of upper limb function following stroke, but the effect of combining trunk restraint with constraint-induced movement therapy is less clear.

Stretching programs

Adopted from: http://advrehabnj.com/2014/10/08/trigger-finger-occupational-therapy/

Spasticity following stroke relates to hypertonicity or increased active tension of the muscle. Contracture may also occur as a result of spasticity and atrophic changes in the mechanical properties of muscles. Since surgery is the only treatment option once a contracture has developed, prevention is encouraged. Stretching may help to prevent contracture formation and, although well-accepted as a treatment strategy, although the evidence base is extremely limited for this intervention.

The methodological details and results of two RCTs evaluating stretching for upper extremity motor rehabilitation are presented in Table 10.

Table 10. RCTs evaluating stretching interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
You et al. (2014) RCT (5) N_{Start}=45 N_{End}=41 TPS=Chronic	E1: Stretching program + joint stabilizing exercise (combo) E2: Stretching program C: Traditional exercise therapy Duration: 30min/d, 5d/wk for 8wk	E1 vs C • Muscle thickness (+exp) • Motor assessment scale (+exp) E2 vs C • Muscle thickness (+exp$_2$) Motor assessment scale (+exp$_2$) E1 vs E2 • Muscle thickness (-) • Motor assessment scale (-)
Tseng et al. (2007) RCT (7) N_{start}=59 N_{end}=59 TPS=Chronic	E1: Nurse assisted range of motion exercise program E2: Nurse supervised range of motion exercise program C: Usual care Duration: 20-40min/d, 6d/wk for 4wk	E1/E2 vs C • Joint angles (+exp, +exp$_2$) • FIM (+exp, +exp$_2$)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about stretching programs

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Stretching programs** may produce greater improvements in spasticity than **conventional therapy**.	1	You et al. 2014

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Stretching programs** may produce greater improvements in range of motion than **conventional therapy**.	1	Tseng et al. 2007

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Stretching programs** may produce greater improvements in performance of activities of daily living than **conventional therapy**.	2	You et al. 2014; Tseng et al. 2007

Key points

Stretching programs may improve some aspects of upper limb function following stroke.

Orthotics

Adopted from: https://www.amazon.com/Soft-Resting-Hand-Splint-Left/dp/B007G4TVIK

Upper limb orthotic devices such as splints or kinesthetic tape are generally used to minimize or prevent contractures, reduce spasticity and pain, and prevent edema poststroke (Lannin & Herbert, 2003). Arm weighted support rehabilitation through orthic devices can facilitate recovery of hand movements through performing semiautonomous rehabilitation programs (Bartolo et al. 2014).

14 RCTs were found that used orthotic devices for upper extremity motor rehabilitation (Choi et al. 2016a; Choi et al. 2016b; Lannin et al. 2016; Kim et al. 2015; Bartolo et al. 2014; Page et al. 2013; Barry et al. 2012; Basaran et al. 2012; Jung et al. 2011; Lannin et al. 2007; Lannin et al. 2003; Langlois et al. 1991; Poole et al. 1990; Rose et al. 1987), the methodological details and results of these RCTs are presented in Table 11.

Table 11. RCTs evaluating orthotic devices for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Choi et al. (2016a) RCT (5) N_{Start}=30 N_{End}=30 TPS=Subacute	E: Hand Splints and a General Rehabilitation Program C: General Rehabilitation Program Duration: 30min/d, 5d/wk for 12wk	• Modified Ashworth Scale (-)
Choi et al. (2016b) RCT (4) N_{Start}=52 N_{End}=52 TPS=Chronic	E: Dorsal Resting Hand Splint C: Volar Resting Hand Splint Duration: 30min/d, 5dwk for 8wk	• Modified Ashworth Scale (+exp) • Active Range of Motion (+exp)
Lannin et al. (2016) RCT (5) N_{Start}=9 N_{End}=6 TPS=Acute	E: Task-specific training + training with the Saebo-Flex device C: Task-specific training Duration: 45-60min/session, 1-3sessions/d, 5-7d/wk for 4-12wk	• Motor Assessment Scale (-) • Box and Block Test (-) • Grip Strength (-)
Kim et al. (2015) RCT (7) N_{Start}=30 N_{End}=30 TPS=Subacute	E: Taping C: No taping Duration: 30min/d, 3d/wk for 28wk	• Manual Function Test (+) • Modified Motor Assessment Scale (+exp)
Bartolo et al. (2014) RCT (8) N_{Start}=28 N_{End}=28 TPS=Acute	E: Arm orthosis C: Conventional physiotherapy Duration: 30min/d, 6d/wk for 2wk	• Arm abduction (+exp) • Arm adduction (+exp) • Arm flexion (+exp) • Arm extension (+exp) • Normalized jerk (+exp) • Fugl Meyer Assessment (-) • Modified Ashworth Scale (-)
Page et al. (2013) RCT (6) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Myomo brace C: Repetitive task practice Duration: 30min/d, 3d/wk for 8wk	• Fugl Meyer Assessment (-) • Canadian Occupational Performance Measure (-) • Stroke Impact Scale (-)
Barry et al. (2012) RCT (7) N_{start}=22 N_{end}=19 TPS=Subacute	E: Dynamic hand orthosis C: Manual assisted therapy Duration: 15min/d, 4d/wk for 6wk	• Grip strength (-) • Action Research Arm Test (-) • Box and Block Test (-) • Stroke Impact Scale (-)
Basaran et al.(2012) RCT (6) N_{start}=39 N_{end}=39 TPS=Chronic	E1: Volar splint E2: Dorsal splint C: No splint Duration: up to 10h/d for 5wk	E1 vs E2 vs C • Modified Ashworth Scale (-) • Passive range of motion (-)
Jung et al. (2011) RCT (4) N_{Start}=21 N_{End}=21 TPS=Chronic	E: Hand stretching/splint device C: No splint Duration: 40min/d, 6d/wk for 3wk	• Modified Ashworth Scale (+exp)
Lannin et al. (2007) RCT (7) N_{start}=63 N_{end}=63 TPS=Acute	E1: Extension splint E2: Neutral splint C: No splint Duration: 9-12h/d for 4wk	• Wrist contracture (-)
Lannin et al. (2003)	E: Hand splint	• Wrist flexor (-)

RCT (8) N_{start}=28 N_{finish}=27 TPS=Subacute	C: No hand splint Duration: up to 12h/d, 5d/wk for 4wk	• Finger flexor (-)
Langlois et al. (1991) RCT (3) N_{start}=9 N_{end}=9 TPS=Chronic	E1: Spint 22hr/d E2: Splint 12hr/d E3: Splint 6hr/d Duration: 6, 12, or 22h/d for 4wk	• Spasticity (-)
Poole et al. (1990) RCT (5) N_{start}=18 N_{end}=18 TPS=Acute	E: Splint C: No splint Duration: 30min/d, 5d/wk for 3wk	• Fugl Meyer Assessment (-)
Rose et al. (1987) RCT (4) N=30	E1: Dorsal orthosis E2: Volar orthosis C: No orthosis Duration: 2h	E1/E2 vs C • Passive range of motion (+exp) E1 vs C • Spontaneous flexion (+exp) E2 vs C • Spontaneous flexion (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about orthotic devices

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Orthotic devices** may not have a difference in efficacy when compared to **conventional therapy, repetitive task practice, or no orthotic device** for improving motor function.	5	Kim et al. 2015; Bartolo et al. 2014; Page et al. 2013; Barry et al. 2012; Poole et al. 1990

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Orthotic devices** may not have a difference in efficacy when compared to **conventional therapy, repetitive task practice, or no orthotic device** for improving dexterity.	2	Lannin et al. 2016; Barry et al. 2012

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Orthotic devices** may not have a difference in efficacy when compared to **conventional therapy, repetitive task practice, or no orthotic device** for improving spasticity.	7	Choi et al. 2016a; Choi et al. 2016b; Bartolo et al. 2014; Basran et al. 2012; Jung et al. 2011; Lannin et al. 2007; Langlois et al. 1991

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Orthotic devices** may produce greater improvements in range of motion than **conventional therapy, repetitive task practice, or no orthotic device**.	5	Choi et al. 2016b; Bartolo et al. 2014; Basran et al. 2012; Lannin et al. 2003; Rose et al. 198

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Orthotic devices** may not have a difference in efficacy when compared to **conventional therapy, repetitive task practice, or no orthotic device** for improving performance of activities of daily living.	4	Lannin et al. 2016; Kim et al. 2015; Page et al. 2013; Barry et al. 2012

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Orthotic devices** may not have a difference in efficacy when compared to **conventional therapy, repetitive task practice, or no orthotic device** for improving muscle strength.	2	Lannin et al. 2016; Barry et al. 2012

Key points

Orthotics may not be beneficial for upper limb rehabilitation following stroke.

Mirror Therapy

Adopted from: https://www.saebo.com/shop/saebo-mirror-box/

In mirror therapy, a mirror is placed beside the unaffected limb, blocking view of the affected limb and creating an illusion of two limbs as if they are both functioning normally. Mirror therapy functions through a process known as mirror visual feedback wherein the movement of one limb is perceived as movement from the other limb (Deconinck et al. 2015). In the brain, mirror therapy is thought to induce neuroplastic changes that promote recovery by increasing excitability of the ipsilateral motor cortex which projects to the paretic limb (Deconinck et al. 2015). Ramachandran et al. (1995) first used this method to understand the effect of vision on phantom sensation and pain in arm amputees. This method has since been adapted from its original use as a means to enhance upper-limb function following stroke (Sathian et al. 2000).

A total of 25 RCTs were found that evaluated mirror therapy for upper extremity rehabilitation poststroke. Of these 18 RCTs looked at mirror therapy compared to conventional rehabilitation or the Bobath concept approach (Radajewska et al. 2017; Colomer et al. 2016; Gurbuz et al. 2016; Kim et al. 2016; Lim et al. 2016; Pervane Vural et al. 2016; Arya et al. 2015; Cristina et al. 2015; Park et al. 2015; Invernizzi et al. 2013; Radajewska et al. 2013; Timmerman et al. 2013; Wu et al. 2013a; Lee et al. 2012; Michielsen et al. 2011; Dohle et al. 2009; Yavuzer et al. 2008; Altschuler et al. 1999). Two RCTs looked at mirror therapy with bilateral arm training (Rodrigues et al. 2016; Samuelkamaleshkumar et al. 2014), mirror therapy combined with: transcranial direct current stimulation (Cho et al. 2015), functional electrical stimulation (Kim et al. 2015), neuromuscular electrical stimulation (Yun et al. 2011), rTMS (Ji et al. 2014), and in a group or individual setting (Thieme et al. 2012).

The methodological details and results of these 25 RCTs are presented in Table 12.

Table 12. Summary of RCTs evaluating mirror therapy for the upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Mirror therapy compared to conventional rehabilitation		
Radajewska et al. (2017) RCT (5) N_{Start}=60 N_{End}=60 TPS=Subacute	E: Mirror therapy C: Conventional rehabilitation Duration: 30min/d, 5d/wk for 3wk	• Frenchay Arm Test (+exp)
Colomer et al. (2016) RCT (7) N_{Start}=34 N_{End}=31 TPS=Chronic	E: Mirror Therapy C: Passive Mobilization Duration: 45min/d, 3d/wk for 8wk	• Nottingham Sensory Assessment (+exp) • Fugl-Meyer Assessment (-)
Gurbuz et al. (2016) RCT (6) N_{Start}=31 N_{End}=31 TPS=Subacute	E: Mirror Therapy C: Conventional Therapy Duration: 60-120min/d, 5d/wk for 4wk	• Brunnstrom Recovery Stage (-) • Fugl-Meyer Assessment (+exp) • Function Independence Measure (-)
Kim et al. (2016) RCT (5) N_{Start}=25 N_{End}=25 TPS=Chronic	E: Mirror Therapy C: Conventional Therapy Duration: 30min/d, 5dwk for 4wk	• Action Research Arm Test (+exp) • Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp) • Functional Independence Measure (+exp)
Lim et al. (2016) RCT (5) N_{Start}=60 N_{End}=60 TPS=?	E: Mirror Therapy C: Sham Therapy Duration: 20min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Modified Barthel Index (+exp) • Brunnstrom Recovery Stage (-)
Pervane Vural et al. (2016) RCT (6) N_{Start}=30 N_{End}=30 TPS=Subacute	E: Mirror Therapy C: Conventional rehabilitation Duration: 4h/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Visual Analog Scale (+exp) • Brunnstrom Recovery Stage (+exp) • Functional Independence Measure (+exp) • Modified Ashworth Scale (+exp)
Arya et al. (2015) RCT (8) N_{Start}=33 N_{End}=32 TPS=Chronic	E: Task-based mirror therapy C: Standard Rehabilitation Duration: 90min/d, 5d/wk for 8wk	• Fugl-Meyer Assessment (+exp)
Cristina et al. (2015) RCT (6) N_{Start}=15 N_{End}=15 TPS=Subacute	E: Mirror therapy C: Conventional therapy Duration: 30min/d, 5d/wk for 6wk	• Modified Ashworth Scale: writ (+exp) • Bhakta finger flexion scale (+exp)
Park et al. (2015) RCT (6) N_{Start}=30 N_{End}=30 TPS=Chronic	E: Mirror therapy C: Non-reflecting mirror Duration: 5d/wk for 6wk	• Manual Function Test (+exp) • FIM (+exp)
Invernizzi et al. (2013) RCT (7) N_{Start}=26 N_{End}=25 TPS=Acute	E: Mirror therapy C: Conventional therapy Duration: 30-60min/d, 5d/wk for 4wk	• Action Research Arm Test (+exp) • Motricity Index (+exp) • Fugl-Meyer Assessments (+exp)
Radajewska et al. (2013)	E: Mirror therapy	• Frenchay Arm Test (+exp)

RCT (3) N_{Start}=60 N_{End}=60 TPS=?	C: Conventional therapy Duration: 30min/d, 5d/wk for 3wk	
Timmerman et al. (2013) RCT (7) N_{Start}=42 N_{End}=42 TPS=Subacute	E: Mirror therapy C: Bobath concept Duration: 30min/d, 3d/wk for 6wk	• Frenchay Arm Test (-) • Functional Assessment Scale (-) • Wolf Motor Function Test (-)
Wu et al. (2013a) RCT (6) N_{Start}=33 N_{End}=21 TPS=Chronic	E: Mirror therapy C: Conventional therapy Duration: 1.5h/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (-) • ABILHAND (-)
Lee et al. (2012) RCT (5) N_{start}=28 N_{end}=26 TPS=Subacute	E: Mirror therapy C: Standard care Duration: 50min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Brunnstrom recovery stages (+exp) • Manual Function Test (+exp)
Michielsen et al. (2011) RCT (7) N_{Start}=40 N_{End}=40 TPS=Chronic	E: Mirror therapy C: Control therapy Duration: 1h/d, 5d/wk for 6wk	• Action Research Arm Test (-) • ABILHAND (-) • Grip force (-) • Tardieu Scale (-) • Fugl-Meyer Assessment (+exp)
Dohle et al. (2009) RCT (7) N_{Start}=36 N_{End}=36 TPS=Acute	E: Mirror therapy C: Control therapy Duration: 30min/d, 5d/wk for 6wk	• Fugl-Meyer Assessment (-)
Yavuzer et al. (2008) RCT (7) N_{Start}=40 N_{End}=40 TPS=Subacute	E: Mirror Therapy C: Sham Therapy Duration: 2-5h/d, 5d/wk for 4wk	• Brunnstrom Recovery Stages (+exp) • Funtional Indepence Measure (+exp) • Modified Ashworth Scale (-)
Altschuler et al. (1999) RCT (7) N_{Start}=40 N_{End}=40 TPS=Chronic	E: Mirror therapy C: Sham therapy Duration: 30min/d, 6d/wk for 4wk	• Brunnstrom Recovery Stage (+exp) • Fugl Meyer self-care Score (+exp) • Modified Ashworth Scale (-)
Mirror therapy combined with bilateral arm training		
Rodrigues et al. (2016) RCT (7) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Mirror therapy and Bilateral Training C: Bilateral Training Duration: 1h/d, 3d/wk for 4wk	• Upper extremity function test (-)
Samuelkamaleshkumar et al. (2014) RCT (7) N_{Start}=20 N_{End}=20 TPS=Subacute	E: Mirror therapy + bilateral arm training C: Control group Duration: 6h/d, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Brunnstrom Recovery Stage (+exp) • Box and Block Test (+exp) • Modified Ashworth Scale (-)
Mirror therapy combined with tDCS		
Cho et al. (2015) RCT (5) N_{Start}=30 N_{End}=27 TPS=Chronic	E: Mirror therapy + tDCS C: Sham mirror therapy + tDCS Duration: 45min/d, 3d/wk for 6wk	• Box and Block Test (+exp) • Grip strength (+exp) • Jebsen Taylor Hand Function (-) Fugl-Meyer Assessment (-)
Mirror therapy combined with functional electrical stimulation		
Kim et al. (2015)	E: FES + mirror therapy	• Box and Block Test (-)

RCT (6) N_{Start}=28 N_{End}=23 TPS=Chronic	C: FES + sham mirror therapy Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Brunnstrom Recovery Stage (-) • Manual Function Test (+exp)
Mirror therapy combined with neuromuscular electrical stimulation		
Yun et al. (2011) RCT (4) N=60 TPS=Acute	E1: Cyclic NMES + mirror therapy E2: Cyclic NMES E3: Mirror therapy Duration: 30min/d, 5d/wk for 3wk	E1 vs. E2/E3 • Fugl-Meyer Assessment (+exp) • Hand flexion (-) • Wrist flexion (-) • Wrist extension (-) •
Mirror therapy combined with rTMS		
Ji et al. (2014) RCT (7) N_{Start}=35 N_{End}=35 TPS=Chronic	E1: Mirror therapy + rTMS E2: Mirror therapy C: Sham therapy Duration: 30min/d, 5d/wk for 4wk	E1 vs. E2 • Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp) E2 vs. C • Fugl-Meyer Assessment (+exp_2) • Box and Block Test (+exp_2)
Group vs individual mirror therapy		
Thieme et al. (2012) RCT (6) N_{Start}=60 N_{End}=49 TPS=Subacute	E1: Individual mirror therapy E2: Group mirror therapy C: Sham mirror therapy Duration: 30min/d, 4dwk for 5wk	• Action Research Arm Test (-) • Fugl-Meyer Assessment (-) • Barthel Index (-) • Stroke Impact Scale (-) E1 vs. E2 • Modified Ashworth Scale (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about mirror therapy

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Mirror therapy** may produce greater improvements in motor function than **conventional therapy or Bobath concept approaches**.	15	Colomer et al. 2016; Gurbuz et al. 2016; Kim et al. 2016; Lim et al. 2016; Pervane Vural et al. 2016; Arya et al. 2015; Park et al. 2015; Ji et al. 2014; Invernizzi et al. 2013; Timmerman et al. 2013; Wu et al. 2013a; Lee et al. 2012; Michielsen et al. 2011; Dohle et al. 2009; Altschuler et al. 1999
1a	There is conflicting evidence about the effect of **mirror therapy combined with bilateral arm training** to improve motor function when compared to **bilateral arm training or conventional therapy**.	2	Rodrigues et al. 2016; Samuelkamaleshkumar et al. 2014
2	**Mirror therapy combined with tDCS** may not have a difference in efficacy compared to **sham mirror therapy combined with tDCS** for improving motor function.	1	Cho et al. 2015
1b	**Mirror therapy combined with high frequency rTMS** may produce greater improvements in motor function than **mirror therapy on its own or sham stimulation**.	1	Ji et al. 2014
1b	**Mirror therapy combined with FES** may produce greater improvements in motor function than **sham mirror therapy with FES**.	1	Kim et al. 2015
2	**Mirror therapy combined with cyclic NMES** may produce greater improvements in motor function than **mirror therapy or cyclic NMES on their own**.	1	Yun et al. 2011
1b	**Mirror therapy provided in a group setting** may not have a difference in efficacy when compared to **mirror therapy in a one on one setting** to improve motor function.	1	Thieme et al. 2012

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Mirror therapy** may produce greater improvements in dexterity than **conventional therapy or Bobath concept approaches**.	2	Kim et al. 2016; Ji et al. 2014
1b	**Mirror therapy combined with bilateral arm training** may produce greater improvements in dexterity than **bilateral arm training or conventional therapy**.	1	Samuelkamaleshkumar et al. 2014
2	**Mirror therapy combined with tDCS** may produce greater improvements in dexterity than **sham mirror therapy combined with tDCS**.	1	Cho et al. 2015
1b	**Mirror therapy combined with FES** may not have a difference in efficacy compared to **sham mirror therapy with FES** for improving dexterity.	1	Kim et al. 2015

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **mirror therapy** to improve spasticity when compared to **conventional therapy or Bobath concept approaches**.	6	Pervane Vural et al. 2016; Cristina et al. 2015; Wu et al. 2013a; Michielsen et al. 2011; Yavuzer et al. 2008; Altschuler et al. 1999
1b	**Mirror therapy combined with bilateral arm training** may produce greater improvements in spasticity than **bilateral arm training or conventional therapy**.	1	Samuelkamaleshkumar et al. 2014
1b	**Mirror therapy provided in a group setting** may produce greater improvements in spasticity than **mirror therapy administered in a one on one setting**.	1	Thieme et al. 2012

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Mirror therapy combined with cyclic NMES** may not have a difference in efficacy when compared to **cyclic NMES or mirror therapy on their own** for improving range of motion.	1	Yun et al. 2011

PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Mirror therapy** may produce greater improvements in proprioception than **conventional therapy or Bobath concept approaches**.	1	Colomer et al. 2016

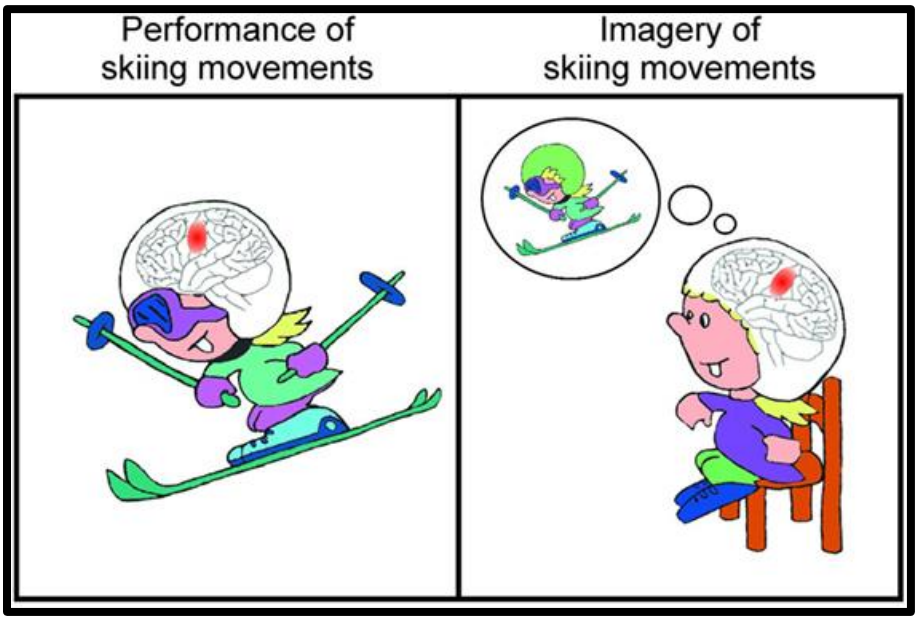
ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **mirror therapy** to improve performance of activities of daily living when compared to **conventional therapy or Bobath concept approaches**.	11	Radajewska et al. 2017; Gurbuz et al. 2016; Kim et al. 2016; Lim et al. 2016; Pervane Vural et al. 2016; Park et al. 2015; Radajewska et al. 2013; Timmerman et al. 2013; Wu et al. 2013a; Michielsen et al. 2011; Yavuzer et al. 2008
1b	**Mirror therapy in a group setting** may not have a difference in efficacy compared to **mirror therapy in a one on one setting** to improve performance of activities of daily living.	1	Thieme et al. 2012

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **mirror therapy** to improve muscle strength when compared to **conventional therapy or Bobath concept approaches**.	2	Invernizzi et al. 2013; Michielsen et al. 2011
2	**Mirror therapy combined with tDCS** may produce greater improvements in muscle strength than **sham mirror therapy combined with tDCS**.	1	Cho et al. 2015

Key points

Mirror therapy on its own or in combination with other interventions can improve many aspects of upper limb function following stroke.

Mental practice



Adopted from: https://www.ucbmsh.com/motor-imagery-for-improvement-of-gait-in-stroke-patient/

Mental practice as the name suggests, involves cognitively rehearsing a specific task by repetitively imagining oneself performing the precise movements involved in the task in the absence of performing the physical movement (Page et al. 2014). Mental practice is speculated to be effective because of its ability to use the same motor schema as when physically practicing the same task through the activation of similar neural regions and networks during mental practice (Page et al. 2014). The use of mental practice was adapted from the field of sports psychology where the technique has been shown to improve athletic performance, when used as an adjunct to standard training methods (Page et al. 2014). The technique is believed to be advantageous in stroke survivors because certain motor skills may be difficult to physically practice; stroke survivors spend a majority of their time inactive and alone; and repetitive task-specific practice is a prerequisite for cortical plasticity and subsequent motor changes (Page et al. 2014). Mental practice can be used to supplement conventional therapy and can be used at any stage of recovery.

17 RCTs evaluated mental practice compared to conventional rehabilitation or a sham intervention for upper extremity motor rehabilitation (Oh et al. 2016; Park et al. 2015b; Liu et al. 2014; Mihara et al. 2013; Oostra et al. 2013; Lee et al. 2012; Letswaart et al. 2011; Page et al. 2011; Bovend'Eerdt et al. 2010; Riccio et al. 2010; Liu et al. 2009b; Muller et al. 2007; Page et al. 2007; Page et al. 2005; Liu et al. 2004; Page et al. 2001; Page et al. 2000). Two RCTs combined mental practice with modified constraint induced movement therapy (mCIMT) compared to mCIMT on its own (Park et al. 2015a; Page et al. 2009). Another RCT combined mental practice with Nintendo Wii virtual reality interactive game training compared to Nintendo Wii training on its own (Park et al. 2016).

The methodological details and results of all 20 RCTs evaluating mental practice interventions for upper extremity motor rehabilitation are presented in Table 13.

Table 13. RCTs evaluating mental practice interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Oh et al. (2016) RCT Crossover (7) N_{Start}=10 N_{End}=10 TPS=Chronic	E: Mental Practice C: Conventional Therapy Duration: 20min/d, 3d/wk for 3wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-)
Park et al. (2015b) RCT (6) N_{Start}=29 N_{End}=29 TPS=Chronic	E: Mental practice C: Physical therapy Duration: 10min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp) • Modified Barthel Index (+exp)
Liu et al. (2014) RCT (7) N_{Start}=20 N_{End}=20 TPS=Subacute	E: Motor imagery + mental practice of affected hand C: Motor imagery + mental practice of unaffected hand Duration: 45min/d, 5d/wk for 4wk	• Action Research Arm test (+exp)
Mihara et al. (2013) RCT (9) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Mental practice C: Sham intervention Duration: 20min/d, 3d/wk for 2wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm test (-)
Oostra et al. (2013) RCT (8) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Mental practice C: Physical training Duration: 30min/d, 5d/wk for 6wk	• Action Research Arm Test (+exp)
Ietswaart et al. (2011) RCT (7) N_{start}=121 N_{end}=101 TPS=Subacute	E1: Motor imagery E2: Attention placebo C: Usual care Duration: 45min/d, 3d/wk for 4wk	• Action Research Arm Test (-)
Page et al. (2011) RCT (6) N_{start}=32 $N_{end=}$29 TPS=Subacute	E: Audiotaped mental practice C: Audiotaped sham intervention Duration: 30min/d, 3d/wk for 10wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-)
Bovend'Eerdt et al. (2010) RCT (8) N_{start}=50 N_{end}=48 TPS=Chronic	E: Mental practice C: Conventional therapy Duration: 30min/d, 2-3d/wk for 5wk	• Barthel Index (-) • Nottingham Extended ADL (-) • Action Research Arm Test (-)
Riccio et al. (2010) RCT Crossover (5) N_{start}=36 N_{end}=36 TPS=Chronic	E: Mental practice C: Conventional rehabilitation Duration: 1h/d, 5d/wk for 3wk	• Motricity Index (+exp) • Arm Function Test (+exp)
Liu et al. (2009b) RCT (5) N_{start}=35 N_{end}=35 TPS=Subacute	E: Mental Imagery C: Conventional Functional Rehabilitation Duration: 1h, 5d/wk for 3wk	• Improvement in Trained Tasks (+exp)
Müller et al. (2007) RCT (4)	E1: Mental practice E2: Motor practice	E1/E2 vs. C • Jebsen Hand Function Test: (+exp$_1$, +exp$_2$)

N_{start}=17 N_{end}=17 TPS=Acute	C: Conventional therapy Duration: 30min/d, 5d/wk for 4wk	• Pinch grip: (+exp_1, +exp_2)
Page et al. (2007) RCT (6) N_{start}=32 N_{end}=32 TPS=Chronic	E: Mental Practice C: Sham Relaxation Exercise Intervention Duration: 30min/d, 2d/wk for 6wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp)
Page et al. (2005a) RCT (6) N_{start} =11 N_{end}=8 TPS=Chronic	E: Mental practice C: Relaxation techniques Duration: 30min/d, 2d/wk for 6wk	• Action Research Arm Test (+exp) • Motor Activity Log: Amount of Use (+exp), Quality of Movement (+exp)
Liu et al. (2004) RCT (4) N_{start}=49 N_{end}=46 TPS=Acute	E: Mental Imagery C: Functional training Duration: 1h/d, 5d/wk for 3wk	• Fugl-Meyer Assessment (-)
Page et al. (2001) RCT (5) N_{start}=13 N_{end}=13 TPS=Subacute	E: Imagery training C: Occupational therapy Duration: 10min/d, 4d/wk for 6wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp)
Page et al. (2000) RCT (4) N_{start}=16 N_{end}=13 TPS=Chronic	E: Imagery training C: Occupational therapy Duration: 30min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp)
Mental practice combined with mCIMT		
Park et al. (2015a) RCT (7) N_{Start}=26 N_{End}=26 TPS=Chronic	E: Mental practice + mCIMT C: mCIMT Duration: 30min/d, 5d/wk for 6wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp) • Modified Barthel Index (+exp)
Page et al. (2009) RCT (4) N_{start}=10 N_{end}=10 TPS=Chronic	E: Mental practice + Modified Constraint Induced Movement Therapy C: Modified Constraint Induced Movement Therapy Duration: 30min/d, 5d/wk for 10wk	• Action Research Arm Test (+exp) • Fugl-Meyer Assessment (+exp)
Nintendo Wii combined with mental practice		
Park et al. (2016) RCT (7) N_{Start}=30 N_{End}=30 TPS=Chronic	E: Nintendo Wii + mental practice C: Nintendo Wii Duration: 5min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about mental practice

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Mental practice** may produce greater improvements in motor function than **conventional rehabilitation or a sham intervention**.	15	Oh et al. 2016; Park et al. 2015b; Liu et al. 2014; Mihara et al. 2013; Oostra et al. 2013; Lee et al. 2012; Page et al. 2011; Bovend'Eerdt et al. 2010; Riccio et al. 2010; Muller et al. 2007; Page et al. 2007; Page et al. 2005; Liu et al. 2004; Page et al. 2001; Page et al. 2000
1b	**Mental practice combined with mCIMT** may produce greater improvements in motor function than **mCIMT** on its own.	2	Park et al. 2015a; Page et al. 2009
1b	**Mental practice combined with Nintendo Wii training** may not have a difference in efficacy compared to **Nintendo Wii training on its own** for improving motor function.	1	Park et al. 2016

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **mental practice** to improve performance of activities of daily living when compared to **conventional rehabilitation or a sham intervention**.	6	Oh et al. 2016; Park et al. 2015b; Rajeesh et al. 2015; Bovend'Eerdt et al. 2010; Liu et al. 2009b; Page et al. 2005
1b	**Mental practice combined with mCIMT** may produce greater improvements in performance of activities of daily living than **mCIMT on its own**.	1	Park et al. 2015a
1b	**Mental practice combined with Nintendo Wii** training may not have a difference in efficacy compared to **Nintendo Wii training on its own** for improving performance of activities of daily living.	1	Park et al. 2016

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Mental practice** may produce greater improvements in muscle strength than **conventional rehabilitation or a sham intervention**.	2	Riccio et al. 2010; Muller et al. 2007

Key points

Mental practice, alone or in combination with constraint-induced movement therapy, may be beneficial for upper limb rehabilitation following stroke.

Mental practice in combination with virtual reality training may not be beneficial for upper limb function.

Action observation

Adopted from: https://www.youtube.com/watch?v=QE3CUhmKi7U

Action observation is a form of therapy whereby an individual observes another individual performing a motor task, either on a video or a real demonstration, and then may attempt to perform the same task themselves. For example, the patient may be instructed to watch a video showing an adult stretching out his hand to pick up a cup, bringing the cup to his mouth, and then returning the cup to its initial position - the act of drinking. After observing the video sequence for a time, the participants may or may not be asked to perform the same action (Borges et al. 2018).

The therapy is considered a multisensory approach designed to increase cortical excitability in the primary motor cortex by activating central representations of actions through the mirror neuron system (Kim and Kim, 2015). Although action observation has been evaluated mainly in healthy volunteers, a few studies have evaluated its benefit in motor relearning following stroke.

Seven RCTs were found that evaluated action observation techniques compared to conventional rehabilitation or sham action observation for upper extremity motor rehabilitation (Kuk et al. 2016; Kim and Kim, 2015; Zhu et al. 2015; Sale et al. 2014; Cowles et al. 2013; Franceschini et al. 2012; Ertelt et al. 2007); their methodological details and results are presented in Table *x*.

Table 14. RCTs evaluating action observation interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Fu et al. 2017 RCT (5) N_{Start}=70 N_{End}=53 TPS=Subacute	E: Video clip of 30 actions relating to sjhoulder, elbow, wrist, forearm and hand movements. C: Conventional therapy Duration: 20min, 6x/wk for 8 wk	• Fugl-Meyer Assessment (-) • Wolf motor function test (-) • Modified Barthel Index (-)
Kuk et al. (2016) RCT (5) N_{Start}=22 N_{End}=20	E: Video clip of a motor task followed by execution of the same motor task C: Pictures of landscapes followed by execution of the motor task Duration: 1min/d for 5d	• Box and Block Test (+exp)
Kim and Kim (2015) RCT (6) N_{Start}=12 N_{End}=12	E: Action observation + occupational therapy C: Placebo observation + occupational therapy Duration: 30min/d, 5d/wk for 6wk	• Wolf Motor Function Test (-)
Zhu et al. (2015) RCT (5) N_{Start}=70 N_{End}=61	E: Upper Limb Action Observation Therapy C: Conventional Rehabilitation Therapy Duration: 30min/d, 6d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Barthel Index (+exp) • Modified Ashworth Scale (+exp)
Sale et al. (2014) RCT (7) N_{Start}=67 N_{End}=67	E: Action observation C: Standard rehabilitation Duration: 3min/d, 5d/wk for 4wk	• Box and Block Test (+exp) • Fugl Meyer Assessment (+exp)
Cowles et al. (2013) RCT (7) N=29	E: Action observation C: Conventional therapy Duration: 1h/d, 5d/wk for 3wk	• Motricity Index (-) • Action Research Arm Test (+con)
Franceschini et al. (2012) RCT (8) N=102	E: Video footage C: Static images Duration: 15min/d, 5d/wk for 4wk	• Box and Block Test (+exp) • Frenchay Arm Test (-) • Modified Ashworth Scale (-) • FIM (-)
Ertelt et al. (2007) RCT (5) N=15	E: Action observation therapy C: Traditional therapy Duration: 12min/d, 5d/wk for 18d	• Frenchay Arm Test (+exp) • Wolf Motor Function Test (+exp) • Stroke Impact Scale (+exp)
Action observation compared to task-oriented training		
Kim and Bang, 2016 RCT (5) N_{Start}=22 N_{End}=22 TPS=Subacute	E: Action observation C: Task-oriented training Duration: 40min, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Box and block test (+exp) • Modified Barthel Index (+exp) • Modified Ashworth Scale (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about action observation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **action observation interventions** to improve motor function when compared to **conventional rehabilitation or sham action observation**.	6	Fu et al. 2017; Kim and Kim, 2015; Zhu et al. 2015; Sale et al. 2014; Cowles et al. 2013; Ertelt et al. 2007
2	**Action observation** may produce greater improvements in motor function than **task-oriented training**.	1	Kim and Bang, 2016

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Action observation** may produce greater improvements in dexterity than **sham stimulation or conventional therapy**.	3	Kuk et al. 2016; Sale et al. 2014; Franceschini et al. 2012
2	**Action observation** may produce greater improvements in dexterity than **task-oriented training**.	1	Kim and Bang, 2016

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **action observation interventions** to improve activities of daily living when compared to **sham stimulation or conventional therapy**.	4	Fu et al. 2017; Zhu et al. 2015; Franceschini et al. 2012; Ertelt et al. 2007
2	**Action observation** may produce greater improvements in activities of daily living than **task-oriented training**.	1	Kim and Bang, 2016

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Action observation** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving muscle strength.	1	Cowles et al. 2017

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Action observation** may produce greater improvements in spasticity than **sham stimulation or conventional therapy**.	1	Zhu et al. 2015
2	**Action observation** may not have a difference in efficacy when compared to **task-oriented training** for improving spasticity.	1	Kim and Bang, 2016

Key points

Action observation may be beneficial for some aspects of upper limb function following stroke.

Music therapy

Adopted from: https://steinhardt.nyu.edu/site/ataglance/2017/03/music-therapy-helps-with-recovery-post-stroke.html

Music therapy is defined as listening, singing, and creating music with/without rhythm and percussion instruments, and is based on four rehabilitation principles: extended repetition of simple finger and arm movements, auditory-motor coupling to reinforce motor learning due to instant auditory feedback, individualized training, and emotional/motivational support due to the emotions invoked by music and the acquisition of a new skill (Zhang et al. 2016). As such it involves many components of conventional upper limb rehabilitation interventions including repetitive task practice, finger individualization, as well as tactile and auditory feedback (van Wijck et al. 2012). The rehabilitation program can also be shaped by increasing the tempo of the songs or incorporating more difficult music pieces based on individual performance (Jun et al. 2013).

Six RCTs (Scholz et al. 2016; Tong et al. 2015; Thielbar et al. 2014; Van Vugt et al. 2014; Jun et al. 2013; Altenmuller et al. 2009) evaluated the effects of music therapy compared to conventional therapy, task-oriented therapy and sham interventions on improving upper extremity motor rehabilitation.

The methodological details and results of all six RCTs are presented in Table 15.

Table 15. RCTs evaluating music therapy interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Scholz et al. (2016) RCT (4) N_{Start}=25 N_{End}=25 TPS=Acute	E: Music Sonification Therapy C: Sham Movement Training Duration: 30min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Nine Hold Peg Test (-) • Stroke Impact Scale (-)
Tong et al. (2015) RCT (5) N_{Start}=33 N_{End}=30 TPS=Chronic	E: Audible Music Instrumental Training C: Mute Music Instrumental Training Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (+exp)
Thielbar et al. (2014) RCT (6) N_{Start}=14 N_{End}=14 TPS=Chronic	E: Virtual keyboard music playing C: High intensity, task oriented occupational therapy Duration: 1hr/d, 3d/wk for 6wk	• Action Research Arm Test (-) • Fugl Meyer Assessment (+exp) • Jebsen Taylor Hand Function Test (+exp) • Grip strength (-) • Pinch strength (-)
Van Vugt et al. (2014) RCT (4) N_{Start}=36 N_{End}=28 TPS=Subacute	E: Playing piano together C: Playing piano sequentially Duration: 30min/d, 5d/wk for 2wk	• Nine Hole Peg Test (-)
Jun et al. (2013) RCT (4) N_{Start}=40 N_{End}=30 TPS=Acute	E: Music movement therapy C: Routine intervention Duration: 1hr/d, 3d/wk for 8wk	• Shoulder and elbow flexion (+exp) • Arm strength (-) • Modified Barthel Index (-)
Altenmüller et al. (2009) RCT (5) N_{Start}=62 N_{End}=62 TPS=Acute	E: MIDI piano and electronic drum training + conventional therapy C: Conventional therapy only Duration: 1hr/d, 5d/wk for 3wk	• Box and Block Test (+exp) • Nine Hole Pegboard Test (+exp) • Action Research Arm Test (+exp) • Finger/Hand tapping (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about music therapy

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **music therapy** to improve motor function when compared to **conventional therapy, task-oriented therapy and sham interventions**.	4	Scholz et al. 2016; Tong et al. 2015; Thielbar et al. 2014; Altenmuller et al. 2009

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Music therapy** may not have a difference in efficacy when compared to **conventional therapy, task-oriented therapy and sham interventions** for improving performance of activities of daily living.	1	Scholz et al. 2016, Jun et al. 2013

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Music therapy** may not have a difference in efficacy when compared to **conventional therapy, task-oriented therapy and sham interventions** for improving muscle strength.	2	Thielbar et al. 2014, Jun et al. 2013

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	There is conflicting evidence about the effect of **music therapy** to improve dexterity when compared to **conventional therapy, task-oriented therapy and sham interventions**.	3	Scholz et al. 2016, Van Vugt et al. 2014, Altenmuller et al. 2009

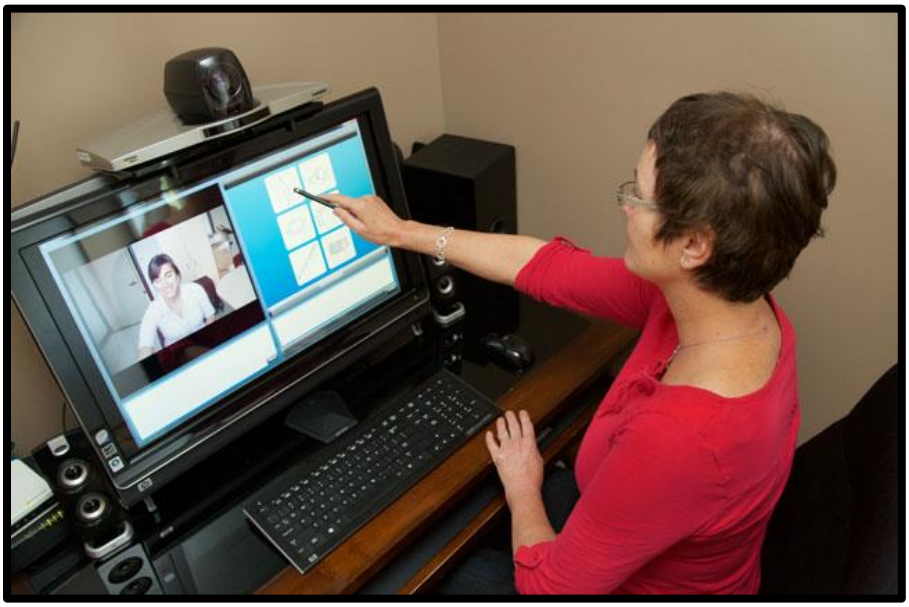
RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Music therapy** may produce greater improvements in range of motion than **conventional therapy, task-oriented therapy and sham interventions**.	1	Jun et al. 2013

Key points

The literature is mixed regarding music therapy for upper limb rehabilitation following stroke.

Technology based interventions

Telerehabilitation



Adopted from: http://www.telereadaptation.com/en/projet/telerehabilitation-in-speech-therapy/

Telerehabilitation is the process of providing rehabilitation services remotely through information and communication technologies (e.g. a kiosk, telephone and computer) (Dodakian et al. 2017; Emmerson et al. 2017). This rehabilitation method is particularly useful for patients who cannot access a rehabilitation center (Benvenuti et al. 2014). Additionally, this intervention can be delivered for a longer duration and at a reduced cost when compared to therapies provided in the inpatient rehabilitation setting (Benvenuti et al. 2014).

Only two RCTs looked at upper limb rehabilitation using telerehabilitation (Emerson et al. 2017; Wolg et al. 2015), though several RCT protocols and observational studies have been published. In one RCT the intervention group was a home exercise program delivered through a tablet (Emerson et al. 2017), while the other RCT delivered a home exercise program through a novel hand robot system (Wolf et al. 2015). Both RCTs were compared to home exercise programs on their own,

The methodological details and results of the two RCTs evaluating telerehabilitation for the upper extremity motor rehabilitation are presented in Table 16.

Table 16. RCTs evaluating telerehabilitation for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Emmerson et al. (2017) RCT (7) N_{Start}=62 N_{End}=58 TPS=Chronic	E: Home exercise program using an electronic tablet with automated reminders C: Paper-based home exercise program Duration: 45min/d, 5d/wk for 4wk	• Wolf Motor Function Test (-) • Grip Strength (-)
Wolf et al. (2015) RCT (7) N_{Start}=99 N_{End}=92 TPS=Subacute	E: Telerehabilitation through an upper extremity hand robot with home exercise program C: Home exercise program only Duration: 3h/d, 5d/wk for 8-12wk	• Fugl Meyer Assessment (-) • Action Research Arm Test (-) • Wolf Motor Function Test (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about telerehabilitation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **telerehabilitation** to improve motor function when compared to **conventional therapy, task-oriented therapy and sham interventions**.	2	Emmerson et al. 2017; Wolf et al. 2015

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Telerehabilitation** may not have a difference in efficacy compared to **home exercise programs** for improving muscle strength.	1	Emmerson et al. 2017

Key points

The literature is mixed regarding telerehabilitation for upper limb rehabilitation following stroke.

Robotics

Adopted from: https://www.strokengine.ca/wp-content/uploads/2015/05/robotics_ARMin-300x226;.jpg http://www.gentle.rdg.ac.uk/103-0325_IMG.JPG; https://cpmsales.net/wp-content/uploads/CENTURA.jpg; http://img.medicalexpo.com/images_me/photo-g/74722-10591286.jpg

Robotic devices can be used to help facilitate passive range of motion, to help maintain range and flexibility, to temporarily reduce hypertonia, and to provide resistance during passive movement. Assistance can also be provided during active movements when a patient cannot complete a movement independently. Robotics may be most appropriate for patients with dense hemiplegia, although robotics can be used with higher-level patients who wish to increase strength by providing resistance during the movement. According to Lum et al. (2002) robotic devices may be the most beneficial in severely impaired patients where unassisted movement is not possible, and especially during the acute phase of recovery during which spontaneous recovery occurs. Krebs et al. (2003) noted that robotic devices rely on the repetition of specific movements to improve functional outcomes.

Upper limb robotic devices can be classified based on the type of robot, the actuation method, the form of transmission, and the sensor used (Yue et al. 2017). The type of robot is based on the alignment of the device and the use and includes end-effectors and exoskeletons (Yue et al. 2017). End-effectors are external to the patient and are connected at a single distal point, whereas exoskeletons are worn by the patient and include mechanical joints that align to the human limb joints (Sicuri et al. 2014; Yue et al. 2017). Actuation of the robot refers to the way in which the energy is produced and includes use of an electric motor, hydraulics, pneumatics, or human muscle (Yue et al. 2017). Transmission refers to the way in which the robot transfers the motion of the actuator to that of the arm, and includes linkages and cables (Yue et al. 2017). Lastly, sensors detect the force and position of the upper limb to provide feedback in response,

and these include physical or bioelectrical signals such as through an electroencephalogram or an electromyogram (Yue et al. 2017).

A table of various robotic devices used in stroke rehabilitation is outlined below (Table 17).

Table 17. Robotic devices used for upper limb rehabilitation post-stroke

Robotic Devices	Description
Arm/Shoulder End-Effectors • MIT-Manus (InMotion) • GENTLE/S (Haptic Master) • MIME (Mirror Image Movement Enhancer) • Neuro-X • Arm Assist • Bi-Manu-Track • Arm Guide • NeReBot • Armeo Boom • Continuous Passive Motion Devices (CYBEX and NORM, Shoulder 600)	MIT-Manus was one of the first robotic devices to be developed and is the most commonly used end-effector (Sicuri et al. 2014). It is a 2-degree-of-freedom robot manipulator that assists in goal-directed shoulder and elbow movements within the horizontal plane, while providing visual, auditory and tactile feedback (Masiero et al. 2007). A commercially available unit (InMotion^2) of this device is also available.
	GENTLE/S or the Haptic Master is a 3-degree-of-freedom haptic interface arm with a wrist attachment mechanism, two embedded computers, a monitor and speakers and an overhead arm support system (Coote et al. 2008). The affected arm is de-weighted through a free moving elbow splint attached to the overhead frame (Coote et al. 2008). The subject is connected to the device by a wrist splint and feedback is provided during task-oriented training (Coote et al. 2008)..
	MIME is a 6-degree-of-freedom robotic manipulator that is attached at the forearm through a splint. It provides bimanual movements as well as unilateral passive, active-assisted, and resisted movements of the hemiparetic upper extremity (Kahn et al. 2006; Burgar et al. 2011). More force is applied to the more affected forearm during goal-directed movements.
	Neuro-X is a 2-degree-of-freedom upper limb rehabilitation robot that assists in performing shoulder abduction-adduction and elbow flexion-extension movements in a horizontal plane. Feedback is provided through use of a monitor on which tasks are performed (Lee et al, 2016).
	Arm Assist is a low-cost robotic system for rehabilitation of the shoulder and elbow post-stroke. The arm is supported through a device while playing interactive games (Tomic et al. 2017).
	Bi-Manu-Track is a 1 degree-of-freedom device that enables bilateral and passive/active practice of forearm and wrist movement (Van Delden et al. 2012).
	The ARM Guide offers 3 degrees of freedom and uses a motor and chain drive to move the user's hand along a linear rail, which assists reaching in a straight-line trajectory (Kahn et al. 2006).
	The NeReBot is a 3-degrees-of-freedom, cable-driven device that produces sensorimotor stimulation and spatial movements of the shoulder and elbow. It is portable and can be used when the patient is either prone or sitting (Rosati et al. 2007; Masiero et al. 2007).
	Armeo Boom is a 3-degree-of-freedom cable-driven manipulator (Sicuri et al. 2014).
	A continuous passive motion device mobilizes a joint through supporting repetitive and reproducible movements (Hu et al. 2009).
Arm/Shoulder Exoskeletons • ARMin • Pneu-WREX • Armeo Spring	ARMin is 7-degree-of-freedom exoskeleton robot that provides intensive and task-specific training to target improvements in motor function (Klamroth-Marganska et al. 2014).
	Pneu-WREX is 4-degree-of-freedom pneumatically actuated upper extremity orthosis that provides robot assisted movement rehabilitation (Reinkensmeyer et al. 2012).
	Armeo Spring is 5-degree-of-freedom exoskeleton robot with an adjustable suspension system (Gijbels et al. 2011). Auditory and visual feedback are provided through the virtual reality system while various functional tasks are performed (Gijbels et al. 2011).
Hand End-Effectors • Amadeo	The Amadeo assists in hand rehabilitation, having an end-effecter design. It helps with finger movements to allow for synchronization (Sale et al. 2014).
Hand Exoskeletons	The Music Glove is used with a game that promotes specific pinching movements to match musical notes displayed on a screen (Zondervan et al. 2016).

• Music Glove • Gloreha (HAnd REhabilitation GLOve) • RAPAEL Smart Glove • FINGER Robot • Modified Hand Exoskeleton Robot • Hand Mentor	The Gloreha hand rehabilitation glove provides repetitive and passive mobilization of the fingers with multisensory feedback through a computing device (Vanoglio et al. 2017).
	The RAPAEL Smart Glove provides a 9-axis movement and position sensors along with acceleration channels, angular rate channels, magnetic field channels to assess wrist movement, and bending sensors to assess finger movement (Shin et al. 2016). The glove is worn during video games that are specifically designed to encourage specific rehabilitation exercises within the wrist and fingers (Shin et al. 2016).
	The FINGER robotic exoskeleton provides assistance with flexion and extension of the finger while playing a musical computer game (Rowe et al. 2017).
	The modified hand exoskeleton robot enables individual finger control through joint movement sensing (Susanto et al., 2015). The robot is used to assist with gestures such as hand grasping/opening as well as finger pinching/opening (Susanto et al. 2015).
	The Hand Mentor robotic device facilitates and assists in movement of the wrist and fingers. While the arm unit stabilizes the forearm, movement in the wrist and fingers are isolated. Visual and auditory feedback are provided through a computer control box (Linder et al. 2015).

54 RCTs were found that evaluated upper limb robotics for motor rehabilitation.

40 RCTs evaluated arm/shoulder end-effectors (Ellis et al. 2018; Hsieh et al. 2017; Kim et al. 2017; Tomic et al. 2017; Fan et al. 2016; Lee et al. 2016; McCabe et al. 2015; Prange et al. 2015; Ang et al. 2014; Hesse et al. 2014; Hsieh et al. 2014; Lemmens et al. 2014; Masiero et al. 2014; Timmermans et al. 2014; Sale et al. 2014; Hsieh et al. 2012; Liao et al. 2012; Abdullah et al. 2011; Burgar et al. 2011; Conroy et al. 2011; Hsieh et al. 2011; Masiero et al. 2011; Lo et al. 2010; Hu et al. 2009; Coote et al. 2008; Hesse et al. 2008; Rabadi et al. 2008; Volpe et al. 2008; Masiero et al. 2007; Kahn et al. 2006; Lum et al. 2006; Masiero et al. 2006; Hesse et al. 2005; Fasoli et al. 2004; Stein et al. 2004; Volpe et al. 2004; Lum et al. 2002; Burgar et al. 2000; Volpe et al. 2000; Volpe et al. 1999).

Four RCTs evaluated arm/shoulder exoskeletons (Daunoraviciene et al. 2018; Brokaw et al. 2014; Klamroth-Marganska et al. 2014; Reinkensmeyer et al. 2012). Two RCTs evaluated hand end-effectors (Sale et al. 2014; Hwang et al. 2012).

Nine RCTs evaluated hand exoskeletons (Rowe et al. 2017; Vanoglio et al. 2017; Shin et al. 2016; Zondervan et al. 2016; Linder et al. 2015; Susanto et al. 2015; Wolf et al. 2015; Friedman et al. 2014; Kutner et al. 2010). One RCT evaluated miscellaneous robotic devices (Bustamante Valles et al. 2016).

The methodological details and results of all 56 RCTs are presented in Table 18.

Table 18. RCTs evaluating robotics for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Arm/Shoulder End-Effectors		
Ellis et al. 2018 RCT (8) N_{Start}=32 N_{End}=32 TPS=Chronic	E: Progressive Abduction Loading Therapy and Horizontal-Plane Viscous Resistance using Robotic Device (Haptic Master) C: Progressive Abduction Loading Therapy Duration: 30min/d, 3d/wk for 8wk	• Maximum Reaching Distance (+exp) • Elbow Extension and Rotation (+exp) • Shoulder Extension, Abduction (+exp) • Fugl-Meyer Assessment (-) • Motor Activity Log (-) • Quality of Movement (-) • Rancho Los Amigos Functional Test for the Hemiparetic Upper Extremity (-)
Hsieh et al. (2017) RCT (6) N_{Start} =31 N_{End} =21 TPS=Subacute	E: Bilateral priming robot-aided (Bi-Manu-Track) therapy with task-oriented therapy C: Task-oriented therapy Duration: 90min/d, 5d/wk for 4wk	• Stroke Impact Scale (-) • Fugl-Meyer Assessment (-) • Box and Block Test (-) • Grip Strength (-) • Modified Rankin Scale (-) • Functional Independence Measure (-)
Kim et al. (2017) RCT (5) N_{Start} =33 N_{End} =30 TPS=Chronic	E: External Focus with Robotic Arm (InMotion ARM) C: Internal Focus with Robotic Arm Duration: 45min/d, 3d/wk for 4wk	• Joint Independence (-) • Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-)
Tomic et al. (2017) RCT (7) N_{Start} =26 N_{End} =26 TPS=Subacute	E: ArmAssist Robot C: Conventional Therapy Duration: 30min/d, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) • Barthel Index (-)
Fan et al. (2016) RCT (4) N_{Start}=6 N_{End}=6 TPS=Chronic	E: Robot-assisted bilateral arm therapy (Bi-Manu-Track) C: Dose-matched control therapy Duration: 45min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-)
Lee et al. (2016) RCT (4) N_{Start}=58 N_{End}=44 TPS=Acute	E: Robotic-assisted therapy (Neuro-X) C: Conventional rehabilitation Duration: 1hr/d, 5d/wk for 2wk	• Manual Muscle Test (-) • Manual Function Test (-) • Modified Barthel Index (-)
McCabe et al. (2015) RCT (6) N_{Start}=39 N_{End}=35 TPS=Chronic	E1: Robotic training (InMotion ARM) + motor learning E2: Motor learning + functional electrical stimulation C: Motor learning Duration: 5hr/d, 5d/wk for 12wk	• Arm Motor Ability Test (-) • Fugl-Meyer Assessment (-)
Prange et al. (2015) RCT (7) N_{Start}=70 N_{End}=68 TPS=Acute	E: Arm training with robot (ArmeoBoom) C : Conventional training Duration : 30min/d, 4d/wk for 6wk	• Stroke Upper Limb Capacity Scale (-) • Reaching Distance (-) • Fugl-Meyer Assessment (-)
Ang et al. (2014) RCT (7) N_{Start}=26 N_{End}=25 TPS=Chronic	E: Brain Computer Interface Coupled with MIT-Manus shoulder-elbow robotic feedback C: Training with the MIT-Manus Duration: 2hr/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (-)
Hesse et al. (2014) RCT (8)	E: Group robot therapy (Bi-Manu-Track) + individual arm therapy	• Box and Block Test (-) • Action Research Arm Test (-)

N_{Start}=50 N_{End}=46 TPS=Acute	C: Individual arm therapy Duration: 30min/d, 5d/wk for 6wk	
Hsieh et al. (2014) RCT (8) N_{Start}=48 N_{End}=48 TPS=Chronic	E1: Robotic training (Bi-Manu-Track) + dCIT (distributed constraint induced therapy) E2: Robotic therapy C: Conventional therapy Duration: 1hr/d, 5d/wk for 5wk	E1 vs E2 • Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) E1 vs C • Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) E2 vs C • Fugl-Meyer Assessment: (+exp_2) • Wolf Motor Function Test (+exp_2) • E1 vs E2, E1 vs C & E2 vs C • Motor Activity Log (-)
Lemmens et al. (2014) RCT (7) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Robotic therapy (Haptic Master) C: No robotic therapy Duration: 30min (2x/d), 4d/wk for 8wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Motor Activity Log (-)
Masiero et al. (2014a) RCT (7) N_{Start}=34 N_{End}=30 TPS=Chronic	E: Robotic therapy (NeReBot) C: Standard therapy Duration: 2hr/d, 5d/wk for 5wk	• Fugl-Meyer Assessment (-) • Box and Block test (-) • Frenchay Arm Test (-) • Medical Research Council Scale (-) • Functional Independence Measure (-)
Timmermans et al. (2014) RCT (8) N_{Start}=22 N_{End}=22 TPS=Chronic	E: Robotic arm training (Haptic Master) C: Task oriented arm training Duration: 30min (2x/d), 4d/wk for 8wk	• Fugl-Meyer Assessment (-) • Action Research Arm test (-) • Motor Activity Log (-)
Sale et al. (2014) RCT (6) N_{Start}=53 N_{End}=53 TPS=Acute	E: Robot aided therapy (MIT-Manus) + reaching tasks C: Reaching tasks Duration: 1hr/d, 2d/wk for 10wk	• Fugl-Meyer Assessment (+exp) • Motricity Index (+exp)
Hsieh et al. (2012) RCT (7) N_{start}=54 N_{end}=53 TPS=Chronic	E1: High intensity robotic therapy (Bi-Manu-Track) E2: Low intensity robotic therapy C: Conventional therapy Duration: 90min/d, 5d/wk for 3wk	E1 vs E2 • Fugl-Meyer Assessment: (+exp) E1 vs C • Fugl-Meyer Assessment: (+exp) E1 vs E2 & E1 vs C • Medical Research Council Scale (-) • Motor Activity Log (-) • Stroke Impact Scale (-)
Liao et al. (2012) RCT (7) N_{start}=20 N_{end}=20 TPS=Chronic	E: Robotic therapy (Bi-Manu-Track) C: Dose-matched conventional therapy Duration: 100min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp) ABILHAND (+exp)
Abdullah et al. (2011) RCT (5) N_{start}=20 N_{end}=20 TPS=Acute	E: Robot assisted therapy C: Dose-matched conventional therapy Duration: *Not Specified*	• Chedoke Arm and Hand Activity Inventory (-)
Burgar et al. (2011) RCT (5) N=54 TPS=Acute	E1: High intensity robotic therapy (MIME) E2: Low intensity robotic therapy C: Conventional therapy Duration: 1hr/d, 3d/wk for 8wk	E1 vs C • Functional Independence Measure (+exp) • Modified Ashworth Scale (-) • Fugl-Meyer Assessment (-)
Conroy et al. (2011) RCT (6) N_{start}=62	E1: Robot-assisted (InMotion ARM) planar reaching	• Fugl-Meyer Assessment (-)

N_{end}=54 TPS=Chronic	E2: Robot-assisted planar and vertical reaching C: Intensive conventional arm therapy Duration: 1hr/d, 3d/wk for 6wk	
Hsieh et al. (2011) RCT (8) N_{start}=18 N_{end}=18 TPS=Chronic	E1: High intensity robot-assisted therapy (Bi-Manu-Track) E2: Low intensity robot-assisted therapy C: Conventional therapy Duration: 45min/d, 3d/wk for 6wk	E1 vs E2 • Fugl-Meyer Assessment: (+exp) E2 vs. C • Fugl-Meyer Assessment (-) E1 vs C • Motor Activity Log (+exp) E1 vs E2/C • Motor Activity Log (-) • ABILHAND (-) • Medical Research Council Scale (-)
Masiero et al. (2011) RCT (5) N_{start}=21 N_{end}=21 TPS=Acute	E: Robotic arm therapy (NeReBot) C: Conventional therapy Duration: *Not Specified*	• Medical Research Council Scale (+exp) • Fugl-Meyer Assessment (-) • Functional Independence Measure (-) • Modified Ashworth Scale (-) • Frenchay Arm Test (-) Box and Block Test (-)
Lo et al. (2010) RCT (7) N_{start}=127 N_{end}=127 TPS=Chronic	E1: Intensive robot assisted therapy (MIT-Manus) E2: Intensive comparison therapy C: Usual care Duration: 1hr/d, 3d/wk for 12wk	E1 vs C • Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-) • Stroke Impact Scale (+exp) • Modified Ashworth Scale (-) E1 vs E2 • Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-) • Stroke Impact Scale (-) • Modified Ashworth Scale (-)
Hu et al. (2009) RCT (5) N_{start}=27 N_{end}=27 TPS=Chronic	E: EMG-driven robot (CYBEX and NORM Continuous Passive Motion) C: Passive motion device Duration: 20min/d, 5d/wk for 7wk	• Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp)
Coote et al. (2008) RCT (6) N_{start}=23 N_{end}=20 TPS=Chronic	E: Robot-mediated therapy (GENTLE/s) C: Sling suspension phase Duration: 30min/d, 3d/wk for 9wk	Fugl-Meyer Assessment (+exp)
Hesse et al. (2008) RCT (8) N_{start}=54 N_{end}=47 TPS=Subacute	E: Computerized arm trainer (Reha-Slide Mechanical Arm Trainer) C: Electrical stimulation Duration: 25min/d, 5d/wk for 6wk	• Fugl-Meyer Assessment (-) • Barthel Index (-)
Rabadi et al. (2008) RCT (5) N_{start}=30 N_{end}=30 TPS=Acute	E1: Robot (MIT-Manus)-unilateral group E2: Ergometer (bilateral) group C: Conventional therapy Duration: 3hr/d, 3d/wk for 4wk	E1 vs E2/C Fugl-Meyer Assessment (-)
Volpe et al. (2008) RCT (5) N_{start}=21 N_{end}=21 TPS=Chronic	E: Sensorimotor arm training delivered by robotic device (MIT-Manus) C: Sensorimotor arm training delivered by a therapist Duration: 1hr/d, 3d/wk for 6wk	• Fugl-Meyer Assessment (-) • Motor Power Scale (-)
Masiero et al. (2007) RCT (5) N_{start}=20 N_{end}=20	E: Robotic Training (NeReBot) C: Exposure to robotic device Duration: 1hr/d, 4d/wk for 5wk	• Fugl-Meyer Assessment (+exp) • Medical Research Council (+exp) • Functional Independence Measure (+exp) • Modified Ashworth Scale (-)

TPS=Acute		
Kahn et al. (2006) RCT (4) N_{start}=19 N_{end}=19 TPS=Chronic	E: Active-assistive reaching exercise using a robotic device (Arm Guide) C: Task-matched amount of reaching without assistance Duration: 40min/d, 6d/wk for 4wk	• Rango Los Amigos Functional Test (-)
Lum et al. (2006) RCT (4) N_{start}=30 N_{end}=23 TPS=Subacute	E1: Robot-unilateral (MIME) E2: Robot-bilateral E3: Robot-combined C: Conventional therapy Duration: 30min/d, 3d/wk for 4wk	E3 vs C • Fugl-Meyer Assessment (+exp$_3$) • Motor Status Score (+exp$_3$) • Functional Independence Measure (-) • Motor power examination (-) • Modified Ashworth Scale (-) E3 vs E1 • Fugl-Meyer Assessment (-) • Motor Status Score (-) • Functional Independence Measure (-) • Motor power examination (-) • Modified Ashworth Scale (-)
Masiero et al. (2006) RCT (5) N_{start}=35 N_{end}=35 TPS=Acute	E: Additional sensorimotor robotic training (NeReBot) C: Exposure to robotic device with no training Duration: 1hr/d, 4d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Motricity Index (+exp) • Functional Independence Measure (+exp) Medical Research Council Scale (-)
Hesse et al. (2005) RCT (8) N_{start}=44 N_{end}=39 TPS=Subacute	E: Computerized arm training enabling repetitive practice (Bi-Manu-Track) C: Electrical stimulation Duration: 20min/d, 5d/wk for 6wk	Fugl-Meyer Assessment (+exp)
Fasoli et al. (2004) RCT (6) N_{start}=56 N_{end}=56 TPS=Acute	E: Robot assisted (MIT-Manus) movement training C: Robot exposure Duration: 90min/d, 2d/wk for 12wk	• Fugl-Meyer Assessment (+exp) • Motor status score (-) • Medical Research Council score (-)
Stein et al. (2004) RCT (5) N_{start}=47 N_{end}=46 TPS=Chronic	E1: Robot-aided (InMotion ARM) progressive resistance training E2: Active-assisted robot-aided exercise Duration: 1hr/d, 4d/wk for 3wk	• Fugl-Meyer Assessment (-) • Strength (-)
Volpe et al. (2004) RCT (4) N_{start}=32 N_{end}=32 TPS=Acute	E: Continuous Passive Motion Device (Shoulder 600) C: Control Duration : 30min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (-) • Motor Status score (-) • Modified Ashworth Scale (-)
Lum et al. (2002) RCT (6) N_{start}=30 N_{end}=27 TPS=Chronic	E: Robot (MIME)-assisted movement training C: Conventional therapy Duration: 1hr/d, 5d/wk for 6wk	• Fugl-Meyer Assessment (+exp) • Strength upper extremity (+exp) • Reach upper extremity (+exp) • Functional Independence Measure (-)
Burgar et al. (2000) RCT (5) N_{start}=21 N_{end}=21 TPS=Chronic	E: Robotic (MIME) device therapy C: Conventional care (physical therapy) Duration: 2hr/d, 3d/wk for 10wk	• Fugl-Meyer Assessment (-) • Functional Independence Measure (-) • Barthel Index (-)
Volpe et al. (2000a) RCT (6) N_{start}=56 N_{end}=56 TPS=Acute	E: Robotic training (MIT-Manus) C: Exposure to the robotic device without training Duration: 30min/d, 3d/wk for 4wk	• Motor Power score: shoulder and elbow (+exp), wrist and hand (-) • Motor Status score: shoulder and elbow (+exp), wrist and hand (-) • Functional Independence Measurer (+exp) • Fugl-Meyer Assessment: (-)
Volpe et al. (1999)	E: Robot (MIT-Manus)	• Motor Status score (+exp)

RCT (6) N_{start}=20 N_{end}=12 TPS=Acute	C: Sham treatment Duration: 45min/d, 5d/wk for 6wk	• Motor Status score (-) • Motor Power score (+exp) • Fugl-Meyer Assessment (-)
Arm/Shoulder Exoskeletons		
Daunoraviciene et al. (2018) Lithuania RCT (5) N_{Start} =34 N_{End} =34 TPS= Subacute	E: Robot-assisted Training (Armeo Spring) C: Conventional Therapy Duration: 1hr/d, 4d/wk for 5wk	• Functional Independence Measure (-) • Fugl-Meyer Assessment (-) • Shoulder Flexion, Abduction, Adduction, and Internal Rotation (+exp) • Elbow Flexion, Supination, and Pronation (+exp) • Wrist Range of Motion (-)
Brokaw et al. (2014) RCT (3) N_{Start}=12 N_{End}=10 TPS=Chronic	E: Robotic therapy (ARMin) C: Conventional therapy Duration: 90min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (+exp) • Box and Bock Test (-)
Klamroth-Marganska et al. (2014) RCT (8) N_{Start}=77 N_{End}=73 TPS= Chronic	E: Robotic therapy (ARMin) C: Conventional treatment Duration: 1hr/d, 3d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Strength (+exp) • Motor Activity Log (-) • Modified Ashworth Scale (-) • Wolf Motor Function test (-)
Reinkensmeyer et al. (2012) RCT (7) N_{start}=26 N_{end}=26 TPS=Chronic	E: Robotic training (Pneu-WREX) C: Conventional tabletop therapy Duration: 1hr/d, 3d/wk for 8wk	• Fugl-Meyer Assessment (-) • Nottingham sensory test (-) • Grip strength (-) • Box and Block Test (-)
Hand End-Effectors		
Sale et al. (2014) RCT (7) N_{Start}=20 N_{End}=20 TPS=Acute	E: Amadeo robotic therapy + physiotherapy C: Occupational therapy Duration : 1hr/d, 3d/wk for 4wk	• Box and Block Test (+exp) • Fugl-Meyer Assessment (+exp)
Hwang et al. (2012) RCT (6) N_{start}=17 N_{end}=17 TPS=Chronic	E: Active Amadeo robot training C: Early passive therapy Duration : 45min/d, 5d/wk for 2wk	• Jebsen-Taylor Hand Function (-) • Fugl-Meyer Assessment (-) • Ashworth Scale (-) • Nine Hole Peg Test (-) • Stroke Impact Scale (-)
Hand Exoskeletons		
Rowe et al. (2017) RCT (7) N_{Start} =30 N_{End} =30 TPS=Chronic	E: High Robotic Assistance Finger Training (FINGER robot) C: Low Robotic Assistance Finger Training Duration: 90min/d, 5d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Box and Block Test (-) • Action Research Arm Test (-) • Nine-Hole Peg Test (-) • Finger Tapping (-) • Motor Activity Log (-) • National Institutes of Health Stroke Scale (-) •
Vanoglio et al. (2017) RCT (7) N_{Start} =30 N_{End} =27 TPS=Acute	E: Robotic Glove with Multisensory Feedback (Gloreha hand rehab glove) C: Conventional Therapy Duration: 30min/d, 3d/wk for 5wk	• Motricity Index (+exp) • Nine Hole Peg Test (+exp) • Grip Strength (+exp) • Pinch Test (+exp) • Quick Version of Disabilities of the Arm, Shoulder, and Hand Questionnaire (+exp)
Shin et al. (2016) RCT (8) N_{Start}=46 N_{End}=46 TPS=Chronic	E: RAPAEL SmartGlove virtual reality task training C: Conventional therapy Duration: 40min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Jebsen Taylor Hand Function Test (+exp) • Stroke Impact Scale (+exp) • Purdue Pegboard Test (-)
Zondervan et al. (2016)	E: Home-based training with a MusicGlove	• Motor Activity Log (+exp)

RCT (6) N_{Start}=18 N_{End}=17 TPS=Chronic	C: Conventional tabletop exercise Duration: 25min/d, 6d/wk for 4wk	• Box and Block Test (-) • 9-Hole Peg Test (-) • Action Research Arm Test (-)
Linder et al. (2015) RCT (5) N_{Start}=99 N_{End}=99 TPS=Acute	E: Robot-assisted therapy program + home exercise program (Hand Mentor) C: Home exercise program Duration: 30min/d, 2d/wk for 5wk	• Stroke Impact Scale (+exp)
Susanto et al. (2015) RCT (7) N_{Start}=19 N_{End}=19 TPS=Chronic	E: Robotic paretic hand therapy (exoskeleton device) C: Task therapy without robotic aid Duration: 1hr/d, 5d/wk for 4wk	• Wolf Motor Function Test (+exp)
Wolf et al. (2015) RCT (6) N_{Start}=99 N_{End}=92 TPS=Acute	E: Telemonitored robotic assisted home exercise therapy program (Hand Mentor) C: Dose-matched usual care home program Duration; 3hr/d, 5d/wk for 8wk	• Wolf Motor Function Test (+exp) • Fugl-Meyer Assessment (-) • Action Research Arm Test (-)
Friedman et al. (2014) RCT (6) N_{Start}=12 N_{End}=12 TPS=Chronic	E1: IsoTrainer E2: Music glove training C: Control Duration: 1hr/d, 3d/wk for 2wk	• Wolf Motor Function Test (-) • Fugl-Meyer Assessment (-) • Action Research Arm Test (-) E2 vs C • Box and Block Test: (+exp_2) • Nine Hole Peg Test:(+exp_2) E1 vs E2 • Box and Block Test: (-) • Nine Hole Peg Test:(-) E1 vs C • Box and Block Test: (-) • Nine Hole Peg Test:(-)
Kutner et al. (2010) RCT (7) N_{start}=30 N_{end}=26 TPS=Subacute/Chronic	E: Robot therapy (Hand Mentor) C: Conventional therapy Duration: 1hr/d, 5d/wk for 6wk	• Stroke Impact Scale (+exp)
Other		
Bustamante Valles et al. (2016) RCT (3) N_{Start}=27 N_{End}=20 TPS=Chronic	E: Rehabilitation using a technology-assisted rehabilitation gymnasium (circuit with various robots) C: Traditional therapy Duration: 2hr/d, 4d/wk for 6wk	• Fugl-Meyer Assessment (-) • Box and Block Test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about robotics

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of various **arm/shoulder end-effectors (MIME, Neuro-X, GENTLE/s/Haptic Master, MIT-Manus/In Motion, NeReBot, ArmeoBoom, continuous passive motion)** to improve motor function when compared to **conventional therapy**.	17	Tomic et al. 2017; Lee et al. 2016; Prange et al. 2015; Lemmens et al. 2014; Masiero et al. 2014; Sale et al. 2014; Abdullah et al. 2011; Burgar et al. 2011; Conroy et al. 2011; Masiero et al. 2011; Lo et al. 2010; Rabadi et al. 2008; Kahn et al. 2006; Lum et al. 2006; Volpe et al. 2004; Lum et al. 2002; Burgar et al. 2000
1a	A specific **arm/shoulder end-effector (Bi-Manu-Track)** may produce greater improvements in motor function than **conventional therapy**.	5	Fan et al. 2016; Hsieh et al. 2014; Hsieh et al. 2012; Liao et al. 2012; Hsieh et al. 2011
1a	**Arm/shoulder end-effectors (Bi-Manu-Track, Haptic Master)** may not have a difference in efficacy when compared to **task-oriented therapy** for improving motor function.	2	Hsieh et al. 2017; Timmermans et al. 2014
1a	**Arm/shoulder end-effectors (Haptic Master, MIT-Manus/InMotion)** may not have a difference in efficacy when compared to **active control therapies (progressive abduction loading therapy, motor learning, or sensorimotor arm training)** for improving motor function.	3	Ellis et al. 2018; McCabe et al. 2015; Volpe et al. 2008
1a	**Arm/shoulder end-effectors (GENTLE, MIT-Manus/InMotion, and continuous passive motion devices)** may produce greater improvements in motor function than **passive control therapies (a sling suspension phase, passive motion, and sham robotics)**.	3	Hu et al. 2009; Coote et al. 2008; Volpe et al. 1999.
1b	**Arm/shoulder end-effectors (MIT-Manus/InMotion, NeReBot)** may produce greater improvements in motor function than **exposure to the robotic device without active assistance**.	4	Masiero et al. 2007; Masiero et al. 2006; Fasoli et al. 2004; Volpe et al. 2000a
1b	**Arm/shoulder end-effectors (Bi-Manu-Track, MIT-Manus/InMotion) provided in a group setting** may not have a difference in efficacy when compared to **arm/shoulder end-effectors provided in a one on one setting** for improving motor function.	2	Kim et al. 2017; Hesse et al. 2014
1b	There is conflicting evidence about the effect of a specific **arm/shoulder end-effector (Bi-Manu-Track)** to improve motor function when compared to **cyclic NMES**.	2	Hesse et al. 2008; Hesse et al. 2005
1b	**Arm/shoulder end-effectors (MIT-Manus/InMotion) combined with additional therapies** may not have a difference in efficacy when compared to using **these robotics alone** for improving motor function.	2	Ang et al. 2014; Stein et al. 2004
1a	There is conflicting evidence about the effect of **arm/shoulder exoskeletons (ARMin, Armeo Spring**	4	Daunoraviciene et al. 2018; Brokaw et al. 2014; Klamroth-

	or Pneu-WREX) to improve motor function when compared to **conventional therapy**.		Marganska et al. 2014; Reinkensmeyer et al. 2012
1a	There is conflicting evidence about the effect of **hand end-effectors (Amadeo hand robot)** to improve motor function when compared to **conventional therapy**.	2	Sale et al. 2014; Hwang et al. 2012
1a	There is conflicting evidence about the effect of **hand exoskeletons (Glohera, SmartGlove, Hand Mentor, Music Glove)** to improve motor function when compared to **conventional therapy**.	6	Rowe et al. 2017; Shin et al. 2016; Zondervan et al. 2016; Wolf et al. 2015; Susanto et al. 2015; Friedman et al. 2014

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **arm/shoulder end-effectors (Bi-Manu-Track, Neuro-X, MIME, NeReBot, and MIT-Manus)** to improve muscle strength when compared to **conventional therapy.**	9	Lee et al. 2016; Masiero et al. 2014; Sale et al. 2014; Hsieh et al. 2012; Hsieh et al. 2011; Masiero et al. 2011; Rabadi et al. 2008; Lum et al. 2006; Lum et al. 2002
1b	A specific **arm/shoulder end-effector (Bi-Manu-Track)** may not have a difference in efficacy when compared to **task-oriented training** for improving muscle strength.	1	Hsieh et al. 2007
2	**Arm/shoulder end-effectors (MIT-Manus//InMotion)** may not have a difference in efficacy when compared to **active control therapies (sensorimotor arm training, progressive resistance training)** for improving muscle strength.	2	Volpe et al. 2008; Stein et al. 2004
1b	There is conflicting evidence about the effect of **arm/shoulder exoskeletons (ARMin or Pneu-WREX)** to improve muscle strength when compared to **conventional therapy**.	2	Klamroth-Marganska et al. 2014; Reinkensmeyer et al. 2012
1b	**Hand exoskeletons (Gloreha)** may produce greater improvements in muscle strength than **conventional therapy**.	1	Vanoglio et al. 2017

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Arm/shoulder end-effectors (MIME, MIT-Manus, NeReBot, and continuous passive motion devices)** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	6	Masiero et al. 2014; Burgar et al. 2011; Masiero et al. 2011; Lo et al. 2010; Lum et al. 2006; Volpe et al. 2004
1b	A specific **arm/shoulder end-effector (Bi-Manu-Track)** may not have a difference in efficacy when compared to **task-oriented training** for improving dexterity.	1	Hsieh et al. 2017
2	**Arm/shoulder end-effectors (Bi-Manu-Track, MIT-Manus/InMotion) provided in a group setting** may not have a difference in efficacy when compared to **arm/shoulder end-effectors provided in a one on one setting** for improving dexterity.	1	Hesse et al. 2014
1b	**Arm/shoulder exoskeletons (ARMin, Pneu-WREX)** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	2	Brokaw et al. 2014; Reinkensmeyer et al. 2012
1a	There is conflicting evidence about the effect of **hand end-effectors (Amadeo hand robot)** to improve dexterity when compared to **conventional therapy**.	2	Sale et al. 2014; Hwang et al. 2012
1a	There is conflicting evidence about the effect of **hand exoskeletons (Glohera, SmartGlove, Music Glove)** to improve dexterity when compared to **conventional therapy**.	4	Vanoglio et al. 2017; Shin et al. 2016; Zondervan et al. 2016; Friedman et al. 2014

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	A specific **arm/shoulder end-effector (Haptic Master) combined with progressive resistance training** may produce greater improvements in range of motion than **progressive resistance training alone**.	1	Ellis et al. 2018
2	**External focus while using an arm/shoulder end-effector (MIT-Manus/InMotion)** may not have a difference in efficacy when compared to **internal focus while using an arm/shoulder end-effector (MIT-Manus/InMotion)** for improving range of motion.	1	Kim et al. 2017
2	A specific **arm/hand exoskeleton (Armeo Spring)** may produce greater improvements in range of motion than **conventional therapy.**	1	Daunoraviciene et al. 2018

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Arm/shoulder end-effectors (MIME, Bi-Manu-Track, Neuro-X, Haptic Master, NeReBot, ArmAssist)** may not have a difference in efficacy when compared to **conventional therapy or task-oriented training** for improving performance of activities of daily living.	16	Hsieh et al. 2017; Tomic et al. 2017; Lee et al. 2016; Hsieh et al. 2014; Lemmens et al. 2014; Masiero et al. 2014; Timmermans et al. 2014; Hsieh et al. 2012; Liao et al. 2012; Burgar et al. 2011; Hsieh et al. 2011; Masiero et al. 2011; Lo et al. 2010; Lum et al. 2006; Lum et al. 2002; Burgar et al. 2000
1a	**Arm/shoulder end-effectors (Haptic Master, MIT-Manus/InMotion)** may not have a difference in efficacy when compared to **active control therapies (progressive abduction loading therapy or motor learning)** for improving performance of activities of daily living.	2	Ellis et al. 2018; McCabe et al. 2015
1b	A specific **arm/shoulder end-effector (Bi-Manu-Track)** may not have a difference in efficacy when compared to **cyclic NMES** for improving performance of activities of daily living.	1	Hesse et al. 2008
1b	**Arm/shoulder exoskeletons (ARMin, Armeo Spring)** may not have a difference in efficacy when compared to **conventional therapy** for improving performance of activities of daily living.	2	Daunoraviciene et al. 2018; Klamroth-Marganska et al. 2014
1b	**Hand end-effector (Amadeo hand robot)** may not have a difference in efficacy when compared to **early passive training** for improving performance of activities of daily living.	1	Hwang et al. 2012
1a	**Hand exoskeletons (MusicGlove, SmartGlove, Hand Mentor)** may produce greater improvements in performance of activities of daily living than **conventional therapy**.	4	Zondervan et al. 2016; Shin et al. 2016; Linder et al. 2015; Kutner et al. 2010
1b	**High assistance FINGER exoskeleton robotic use** may not have a difference in efficacy when compared to **low assistance FINGER exoskeleton robotic use** for improving performance of activities of daily living.	1	Rowe et al. 2017

PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Arm/shoulder exoskeletons (Pneu-WREX)** may produce greater improvements in proprioception than **conventional therapy**.	1	Reinkensmeyer et al. 2012

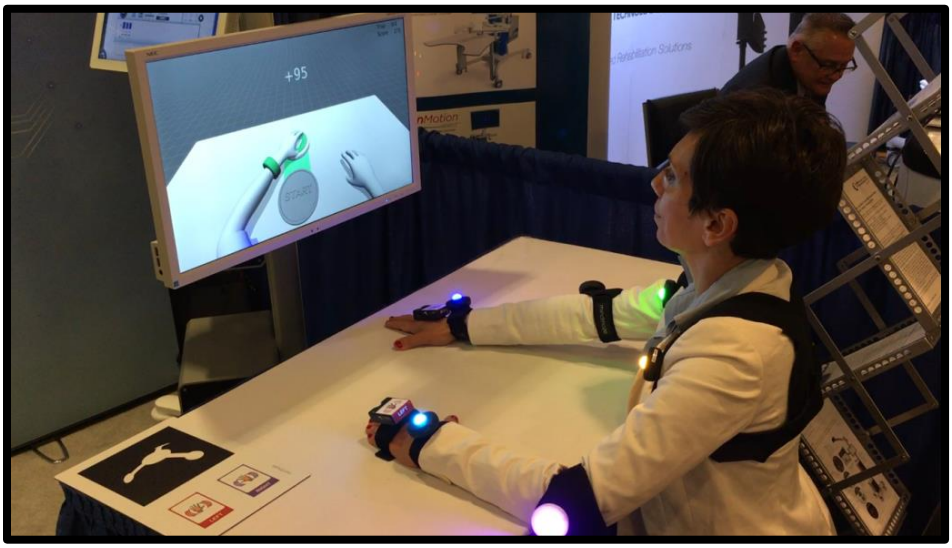
SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Arm/shoulder end-effectors (MIME, MIT-Manus/InMotion, NeReBot, and continuous passive motion devices)** may not have a difference in efficacy when compared to **conventional therapy** for improving spasticity.	6	Masiero et al. 2014; Burgar et al. 2011; Masiero et al. 2011; Lo et al. 2010; Lum et al. 2006; Volpe et al. 2004
2	A specific **arm/shoulder end-effector (NeReBot)** may not have a difference in efficacy when compared to **exposure to the robotic device without active assistance** for improving spasticity.	1	Masiero et al. 2007
1b	**Arm/shoulder exoskeletons (Armin)** may not have a difference in efficacy when compared to **conventional therapy** for improving spasticity.	1	Klamroth-Marganska et al. 2014
1b	**Hand end-effector (Amadeo hand robot)** may not have a difference in efficacy when compared to **early passive training** for improving spasticity.	1	Hwang et al. 2012
1b	**Hand exoskeletons (Gloreha)** may produce greater improvements in spasticity than **conventional therapy**.	1	Vanoglio et al. 2017

Key points

The evidence is mixed regarding arm/shoulder end-effector robotics, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

The evidence is mixed regarding arm/shoulder exoskeleton, hand exoskeleton, and hand end-effector robotics for upper limb rehabilitation.

Virtual reality



Adopted from: https://philadelphia.cbslocal.com/2016/05/15/virtual-reality-stroke-rehab/

Virtual reality interventions are described as the use of immersive multimedia created through computer programs that allows users to engage in simulated environments representative of both real-world and imagined places and objects (Iruthayarajah et al. 2017; Laver et al. 2017). These virtual reality interventions are presented typically as games with haptic feedback, that allow for the creation of a multisensory experience. Virtual reality interventions meet as the four guiding principles of rehabilitation: intensity, task-specific training, biofeedback and motivation (Dias et al. 2019). Research on the use of virtual reality for stroke rehabilitation is increasing as technology becomes more accessible and affordable. This includes using existing gaming consoles (e.g. Nintendo Wii, Xbox Kinect, Playstation Eyetoy) for therapeutic purposes or designing new systems specifically for rehabilitation (Laver et al. 2017).

A total of 36 RCTs evaluating virtual reality interventions for upper extremity motor rehabilitation were found, the characteristics of these interventions are described below.

30 RCTs evaluated virtual reality interventions compared to conventional therapy, recreational therapy or sham interventions (Askin et al. 2018; Faria et al. 2018; Kim et al. 2018; Kiper et al. 2018; Lee et al. 2018; Adie et al. 2017; Ballester et al. 2017; Brunner et al. 2017; Rand et al. 2017; Standen et al. 2017; Turkbey et al. 2017; Choi et al. 2016; Givon et al. 2016; Kong et al. 2016; Lee et al. 2016a; Lee et al. 2016c; Saposnik et al. 2016; da Silva Ribeiro et al. 2015; Shin et al. 2015; Choi et al. 2014; Fan et al. 2014; Kiper et al. 2014; Shin et al. 2014; Thielbar et al. 2014; Duff et al. 2013; Lee et al. 2013; Sin and Lee, 2013; Crosbie et al. 2012; Saposnik et al. 2010; Yavuzer et al. 2008). One RCT compared virtual reality bilateral arm training to bilateral arm training (Lee et al. 2016b). One RCT compared virtual reality training combined with FES to FES alone (Lee et al. 2018), and another combined virtual reality training with tDCS (Lee and Chun, 2014). One RCT combined virtual reality training with a hand orthosis and compared it to conventional therapy (Nijenhuis et al. 2017). One RCT compared virtual reality training to mCIMT (McNulty et al. 2015). One RCT compared asymmetric training with virtual reality to symmetric training (Lee et al. 2014). One RCT compared virtual reality training to no training (Jang et al. 2005).

The methodological details and results of all 36 RCTs are presented in Table 19.

Table 19. RCTs evaluating virtual reality interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Virtual reality training compared to conventional therapy, recreational therapy or sham		
Askin et al. (2018) RCT (6) N_{Start}=40 N_{End}=38 TPS=Chronic	E: Xbox Kinect-based virtual reality training + physical therapy C: Physical therapy Duration: 1h/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Motricity Index (+exp) • Active range of motion (+exp) • Brunnstrom Recovery Stages (-) • Modified Ashworth Scale (-) • Box and Block Test (-)
Faria et al. (2018) RCT (4) N_{Start} =32 N_{End} =24 TPS=Chronic	E: Virtual reality (Reh@Task) C: Time-matched standard occupational therapy Duration: 45min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Chedoke Arm and Hand Activity Inventory (-) • Barthel Index (-) • Motricity Index (-) • Modified Ashworth Scale (-)
Kim et al. (2018) RCT (8) N_{Start} =23 N_{End} =19 TPS=Chronic	E: Kinect-based virtual reality C: Sham virtual reality Duration: 30min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Brunnstrom Stage: Arm and Hand (-) • Box and Block Test (-) • Korean Modified Barthel Index (-) •
Kiper et al. (2018) RCT (7) N_{Start} =139 N_{End} =136 TPS=Subacute	E: Reinforced feedback in virtual environment + conventional rehabilitation C: Conventional rehabilitation Duration: 1h/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp) • National Institute of Health Stroke Scale (+exp)
Lee et al. (2018) RCT (6) N_{Start} =31 N_{End} =30 TPS=Subacute	E: Virtual reality canoe paddle training + conventional therapy C: Conventional therapy Duration: 30min/d, 3d/wk for 5wk	• Manual Function Test (+exp)
Adie et al. (2017) RCT (7) N_{Start} =235 N_{End} =209 TPS=Chronic	E: Wii arm exercises C: Home-based arm exercises Duration: 45min/d for 6wk	• Action Research Arm Test (-) • Stroke Impact Questionnaire (-) • Canadian Occupational Performance Measure (-) • Motor Activity Log (-) •
Ballester et al. (2017) RCT (5) N_{Start} =39 N_{End} =35 TPS=Chronic	E: Home-based virtual reality C: Home-based occupational therapy Duration: 30min/d, 5d/wk, 3wk	• Fugl-Meyer Assessment (-) • Chedoke Arm and Hand Activity Inventory (+exp) • Barthel Index (-) • Medical Research Council Scale (-) • Ashworth Scale (-) • Grip force (-)
Brunner et al. (2017) RCT (5) N_{Start} =120 N_{End} =102 TPS=Subacute	E: Virtual reality training C: Conventional training Duration: 60min/d, 4-5d/wk for 4wk	• Action Research Arm Test (-) • Box and Block Test (-) • Functional Independence Measure (-)
Rand et al. (2017) RCT (7) N_{Start} =24 N_{End}=21 TPS=Chronic	E: Video games self-training C: Traditional self-training Duration: 60min/d, 6d/wk for 5wk	• Action Research Arm Test (-) • Motor Activity Log (-) • Box and Block Test (-)

Standen et al. (2017) RCT (6) N_{Start} =27 N_{End} =18 TPS=Subacute	E: Home-based virtual reality C: Conventional therapy Duration: up to 60min/d, 7d/wk for 8wk	• Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Wolf Grip Strength (+exp) • Nine-Hole Peg Test (-) • Nottingham Extended Activities of Daily Living (-)
Turkbey et al. (2017) RCT (7) N_{Start} =20 N_{End} =19 TPS=Subacute	E: Xbox Kinect virtual reality training + conventional rehabilitation C: Conventional rehabilitation Duration: 60min/d, 5d/wk for 4wk	• Box and Block Test (+exp) • Wolf Motor Function Test (+exp) • Brunnstrom Motor Recovery Stage (+exp) • Functional Independence Measure (-)
Choi et al. (2016) RCT (6) N_{Start}=24 N_{End}=24	E: Virtual reality rehabilitation program + conventional occupational therapy C: Conventional occupational therapy Duration: 30min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (+exp) • Brunnstrom Stage (+exp) • Manual Muscle Test (+exp) • Modified Barthel Index (-)
Givon et al. (2016) RCT (6) N_{Start} =47 N_{End} =43 TPS=Chronic	E: Virtual reality video game therapy C: Traditional therapy Duration: 60min/d, 2d/wk for 12wk	• Action Research Arm Test (-) • Grip strength (-)
Kong et al. (2016) RCT (7) N_{Start} =105 N_{End} =97 TPS=Acute	E: Nintendo Wii virtual reality training C: Conventional therapy Duration: 60min/d, 4d/wk for 3wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Stroke Impact Scale (-) • Functional Independence Measure (-)
Lee et al. (2016a) RCT (7) N_{Start} =26 N_{End} =26 TPS=Chronic	E: Virtual reality-based rehabilitation C: Group-based rehabilitation Duration: 30min/d, 3d/wk for 8wk	• Fugl-Meyer Assessment (+exp) • Manual Function Test (+exp) • Box and Block Test (-) • Modified Barthel Index (-)
Lee et al. (2016c) RCT (5) N_{Start} =14 N_{End} =10 TPS=Acute	E: Canoe game-based virtual reality training + conventional rehabilitation C: Conventional rehabilitation Duration: 30min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (+exp)
Saposnik et al. (2016) RCT (6) N_{Start} =141 N_{End} =121 TPS=Acute	E: Virtual reality training using Nintendo Wii C: Recreational activities Duration: 60min/d, 5d/wk for 2wk	• Wolf Motor Function Test (-) • Box and Block Test (+con) • Stroke Impact Scale (-) • Barthel Index (-) • Functional Independence Measure (-) • Grip Strength (-)
da Silva Ribeiro et al. (2015) RCT (7) N_{Start}=30 N_{End}=30 TPS=Chronic	E: Virtual reality training using Nintendo Wii C: Conventional physical therapy Duration: 20min/d, 3d/wk for 12wk	• Fugl-Meyer Assessment (-)
Shin et al. (2015) RCT (6) N_{Start}=35 N_{End}=32 TPS=Chronic	E: Virtual reality + conventional occupational therapy C: Conventional occupational therapy Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-)
Choi et al. (2014) RCT (8) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Virtual reality therapy using Nintendo Wii C: Conventional occupational therapy Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Box and Block Test (-) • Manual Function Test (-) • Grip strength (-) • Modified Barthel Index (-)
Fan et al. (2014) RCT (7)	E1: Virtual reality E2: Conventional therapy	E1 vs E2 vs E3 vs C • Jebsen-Taylor Hand Function Test (-)

N_{Start}=27 N_{End}=20 TPS=Chronic	E3: Placebo board game C: No treatment Duration: 60min/d, 3d/wk for 3wk	• Stroke Impact Scale (-)
Kiper et al. (2014) RCT (6) N_{Start}=46 N_{End}=44 TPS=Chronic	E: Reinforced feedback in virtual environment + traditional rehabilitation C: Traditional rehabilitation Duration: 2h/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp)
Shin et al. (2014) RCT (5) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Virtual reality training + conventional occupational therapy C: Occupational therapy Duration: 30min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Modified Barthel Index (-) • Medical Research Council Score (-) • Range of Motion (-)
Thielbar et al. (2014) RCT (6) N_{Start}=14 N_{End}=14 TPS=Chronic	E: Virtual reality keypad/glove C: Occupational therapy Duration: 18h/d, 3d/wk for 6wk	• Action Research Arm Test (+exp) • Jebsen-Taylor Hand Function Test (-) • Fugl-Meyer Assessment (-) • Grip Strength (-) • Pinch Strength (-)
Duff et al. (2013) RCT (5) N_{Start}=25 N_{End}=21 TPS=Chronic	E: Adaptive mixed reality rehabilitation C: Traditional therapy Duration: 60min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (+con) • Wolf Motor Function Test (-) • Stroke Impact Scale (-) • Motor Activity Log (-)
Lee et al. (2013) RCT (6) N_{Start}=14 N_{End}=14 TPS=Chronic	E: Xbox Kinect-based virtual reality + conventional occupational therapy C: Conventional occupational therapy Duration: 60min/d, 3d/wk for 6wk	• Manual Muscle Test (-) • Modified Ashworth Scale (-) • Functional Independence Measure (-)
Sin & Lee (2013) RCT (5) N_{Start}=40 N_{End}=35 TPS=Chronic	E: Xbox Kinect-based virtual reality training + conventional occupational therapy C: Conventional occupational therapy Duration: 30min/d, 3d/wk for 6wk	• Range of Motion (+exp) • Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp)
Crosbie et al. (2012) RCT (8) N_{start}=18 N_{end}=17 TPS=Chronic	E: Virtual reality training C: Conventional physiotherapy Duration: 30-45min/d, 3d/wk for 3wk	• Motricity Index (-) • Action Research Arm Test (-)
Saposnik et al. (2010) RCT (7) N_{start}=22 N_{end}=16 TPS=Acute	E: Virtual reality training using Nintendo Wii C: Recreational therapy Duration: 60min/d, 4d/wk for 2wk	• Wolf Motor Function Test (+exp) • Grip strength (-) • Box and Block Test (-) • Stroke Impact Scale (-)
Yavuzer et al. (2008) RCT (6) N_{start}=20 N_{end}=20 TPS=Subacute	E: Playstation EyeToy games + conventional therapy C: Sham therapy + conventional therapy Duration: 30min/d, 5d/wk for 4wk	• Brunnstrom Recovery Stages (-) • Functional Independence Measure (+exp)
Virtual reality bilateral arm training compared to bilateral arm training		
Lee et al. (2016b) RCT (6) N_{Start}=20 N_{End}=18 TPS=Chronic	E: Virtual reality-based bilateral arm training C: Bilateral arm training Duration: 60min/d, 5d/wk for 4wk	• Jebsen Taylor Hand Function Test (+exp) • Box and Block Test (+exp) • Grooved Pegboard Test (+exp) • Digital Manual Muscle Test (+exp)
Virtual reality with FES compared to FES		

Lee et al. (2018) RCT (7) N_{Start}=48 N_{End}=41 TPS=Chronic	E: Virtual reality + functional electrical stimulation C: Functional electrical stimulation Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (-) • Box and Block Test (-) • Jebsen-Taylor Hand Function Test (-) • Stroke Impact Scale (-)
Virtual reality compared to and combined with cathodal tDCS		
Lee & Chun (2014) RCT (7) N_{Start}=64 N_{End}=59 TPS=Subacute	E1: Cathodal transcranial direct current stimulation (tDCS) E2: Virtual reality E3: Cathodal tDCS + virtual reality Duration: 30min/d, 5d/wk for 3wk	E3 vs E2/E1 • Manual Function Test (+exp_3) • Fugl-Meyer Assessment (+exp_3) • Manual Muscle Test (-) • Box and Block Test (-) • Modified Ashworth Scale (-) • Modified Barthel Index (-) E2 vs E1 • Manual Function Test (+exp_2) • Fugl-Meyer Assessment (+exp_2) • Manual Muscle Test (-) • Box and Block Test (-) • Modified Ashworth Scale (-) • Modified Barthel Index (-)
Virtual reality with a hand orthosis compared to conventional therapy		
Nijenhuis et al. (2017) RCT (6) N_{Start} =20 N_{End} =19 TPS=Chronic	E: Hand orthosis + computerised gaming exercises C: Conventional exercise Duration: 30min/d, 6d/wk for 6wk	• Action Research Arm Test (-) • Fugl-Meyer Assessment (-) • Grip Strength (-) • Box and Block Test (-) • Motor Activity Log (-) • Stroke Impact Scale (-)
Virtual reality compared to mCIMT		
McNulty et al. (2015) RCT (7) N_{Start}=41 N_{End}=40 TPS=Chronic	E: Nintendo Wii-based movement therapy C: Modified constraint-induced movement therapy Duration: 60min/d, 5d/wk for 2wk	• Wolf Motor Function Test (-) • Motor Activity Log (-) • Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-) • Box and Block Test (-) • Grooved Pegboard Test (-) • Range of motion (-)
Asymmetric training with virtual reality compared to symmetric training		
Lee et al. (2014) RCT (5) N_{Start}=30 N_{End}=24 TPS=Chronic	E: Asymmetric training using virtual reality + conventional physical therapy C: Symmetric training + conventional physical therapy Duration: 60min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Box and Block test (+exp) • Grip strength (+exp) • Modified Ashworth Scale (-) • Range of motion (+exp)
Virtual reality training compared to no training		
Jang et al. (2005) RCT (5) N_{start}=10 N_{end}= 10 TPS=Chronic	E: Virtual reality training C: No treatment Duration: 60min/d, 5d/wk for 4wk	• Box and Block test (+exp) • Fugl-Meyer Assessment (+exp) • Manual Function Test (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about virtual reality

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **virtual reality interventions** to improve motor function when compared to **conventional therapy, recreational therapy or sham interventions**.	30	Askin et al. 2018; Faria et al. 2018; Kim et al. 2018; Kiper et al. 2018; Lee et al. 2018; Adie et al. 2017; Ballester et al. 2017; Brunner et al. 2017; Rand et al. 2017; Standen et al. 2017; Turkbey et al. 2017; Choi et al. 2016; Givon et al. 2016; Kong et al. 2016; Lee et al. 2016a; Lee et al. 2016c; Saposnik et al. 2016; da Silva Ribeiro et al. 2015; Shin et al. 2015; Choi et al. 2014; Fan et al. 2014; Kiper et al. 2014; Shin et al. 2014; Thielbar et al. 2014; Duff et al. 2013; Sin and Lee, 2013; Crosbie et al. 2012; Saposnik et al. 2010
1b	**Virtual reality bilateral arm training** may produce greater improvements in motor function than **bilateral arm training**.	1	Lee et al. 2016b
1b	**Virtual reality interventions combined with FES** may not have a difference in efficacy when compared to **FES alone** for improving motor function.	1	Lee et al. 2018
1b	**Virtual reality interventions on their own or combined with cathodal tDCS** may produce greater improvements in motor function than **cathodal tDCS**.	1	Lee and Chun, 2014
1b	**Virtual reality training with a hand orthosis** may not have a difference in efficacy when compared to **conventional therapy** for improving motor function.	1	Nijenhuis et al. 2017
1b	**Virtual reality training** may not have a difference in efficacy when compared to **mCIMT** for improving motor function.	1	McNulty et al. 2015
2	**Asymmetric virtual reality training** may produce greater improvements in motor function than **symmetric conventional training**.	1	Lee at al. 2014
2	**Virtual reality training** may produce greater improvements in motor function than **no training**.	1	Jang at al. 2005

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Virtual reality interventions** may produce greater improvements on measures of stroke severity than **conventional therapy**.	1	Kiper et al. 2018

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	There is conflicting evidence about the effect of **virtual reality interventions** to improve range of motion when compared to **conventional therapy, recreational therapy or sham interventions**.	2	Shin et al. 2014; Sin and Lee, 2013
1b	**Virtual reality training** may not have a difference in efficacy when compared to **mCIMT** for improving range of motion.	1	McNulty et al. 2015
2	**Asymmetric virtual reality training** may produce greater improvements in spasticity than **symmetric conventional training**.	1	Lee at al. 2014

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Virtual reality interventions** may not have a difference in efficacy when compared to **conventional therapy, recreational therapy or sham interventions** for improving dexterity.	10	Askin et al. 2018; Kim et al. 2018; Brunner et al. 2017; Rand et al. 2017; Standen et al. 2017; Turkbey et al. 2017; Lee et al. 2016a; Choi et al. 2014; Sin and Lee, 2013; Saposnik et al. 2010
1b	**Virtual reality bilateral arm training** may produce greater improvements in dexterity than **bilateral arm training**.	1	Lee et al. 2016b
1b	**Virtual reality interventions combined with FES** may not have a difference in efficacy when compared to **FES alone** for improving dexterity.	1	Lee et al. 2018
1b	**Virtual reality interventions on their own or combined with cathodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving dexterity.	1	Lee and Chun, 2014
1b	**Virtual reality training with a hand orthosis** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	1	Nijenhuis et al. 2017
1b	**Virtual reality training** may not have a difference in efficacy when compared to **mCIMT** for improving dexterity.	1	McNulty et al. 2015
2	**Asymmetric virtual reality training** may produce greater improvements in dexterity than **symmetric conventional training**.	1	Lee at al. 2014
2	**Virtual reality training** may produce greater improvements in dexterity than **no training**.	1	Jang at al. 2005

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Virtual reality interventions** may not have a difference in efficacy when compared to **conventional therapy, recreational therapy or sham interventions** for improving spasticity.	4	Askin et al. 2018; Faria et al. 2018; Ballester et al. 2017; Lee et al. 2013
1b	**Virtual reality interventions on their own or combined with cathodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving spasticity.	1	Lee and Chun, 2014
1b	**Virtual reality training** may not have a difference in efficacy when compared to **mCIMT** for improving spasticity.	1	McNulty et al. 2015
2	**Asymmetric virtual reality training** may not have a difference in efficacy when compared to **symmetric conventional training** for improving spasticity.	1	Lee at al. 2014

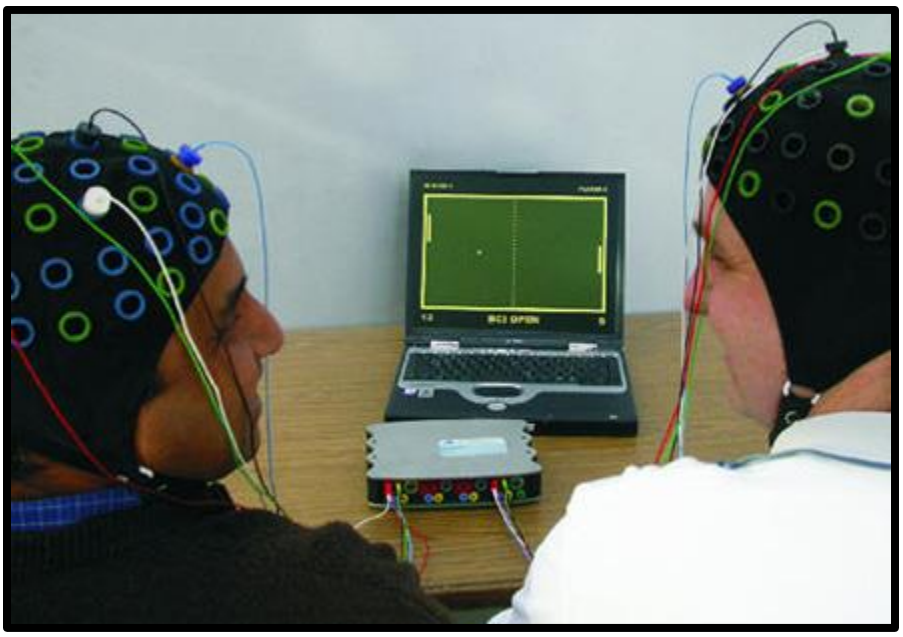
MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Virtual reality interventions** may not have a difference in efficacy when compared to **conventional therapy, recreational therapy or sham interventions** for improving muscle strength.	12	Askin et al. 2018; Faria et al. 2018; Ballester et al. 2017; Standen et al. 2017; Choi et al. 2016; Givon et al. 2016; Saposnik et al. 2016; Choi et al. 2014; Shin et al. 2014; Lee et al. 2013; Crosbie et al. 2012; Saposnik et al. 2010
1b	**Virtual reality bilateral arm training** may produce greater improvements in muscle strength than **bilateral arm training**.	1	Lee et al. 2016b
1b	**Virtual reality interventions on their own or combined with cathodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving muscle strength.	1	Lee and Chun, 2014
1b	**Virtual reality training with a hand orthosis** may not have a difference in efficacy when compared to **conventional therapy** for improving muscle strength.	1	Nijenhuis et al. 2017
2	**Asymmetric virtual reality training** may produce greater improvements in muscle strength than **symmetric conventional training**.	1	Lee at al. 2014

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Virtual reality interventions combined with FES** may not have a difference in efficacy when compared to **FES alone** for improving performance of activities of daily living.	1	Lee et al. 2018
1b	**Virtual reality interventions on their own or combined with cathodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving performance of activities of daily living.	1	Lee and Chun, 2014
1b	**Virtual reality training with a hand orthosis** may not have a difference in efficacy when compared to **conventional therapy** for improving performance of activities of daily living.	1	Nijenhuis et al. 2017
1b	**Virtual reality training** may not have a difference in efficacy when compared to **mCIMT** for improving performance of activities of daily living.	1	McNulty et al. 2015

Key points

Virtual therapy alone may not be more beneficial than conventional therapy for upper limb rehabilitation following stroke, however it may be beneficial for certain aspects of upper limb function when used in combination with conventional or other therapy approaches.

Brain computer interfaces



Adopted from: http://www.tech-faq.com/brain-computer-interface.html

Brain-computer interface (BCI) technology has only recently emerged as a potential rehabilitative treatment option following stroke. BCI records and decodes local brain activity during the performance of a motor movement (Van Dokkum et al. 2015). The decoded brain signals can be configured into visual, auditory or haptic feedback, and even for the control of external devices to help facilitate movement (Van Dokkum et al. 2015). BCI promotes the recruitment of brain areas involved in motor planning and execution and facilitates neural plasticity of neural networks using these areas, helping patients learn to generate normal brain activity or use brain activity to operate training devices (Van Dokkum et al. 2015). The evidence base for this intervention is still however in its infancy.

The methodological details and results of 5 RCTs evaluating BCI for the upper extremity motor rehabilitation in chronic stroke survivors are presented in Table 20.

Table 20. RCTs evaluating brain computer interfaces interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Lin et al. (2018) RCT (6) N_{Start} =15 N_{End} =15 TPS=Chronic	E1: Motion tracking device+ VR game E2: Motion tracking device + brain-computer interface attention-monitoring electroencephalogram device + VR game C: Conventional therapy Duration: 35min/d, 3d/wk for 4wk	E2 vs C • Fugl-Meyer Assessment (exp$_2$) E1 vs C • Fugl-Meyer Assessment (-)
Young et al. (2016) RCT (5) N_{Start}=19 N_{End}=10 TPS=Chronic	E: Brain computer interface training C: No training Duration: 120min/d for 9-15d	• Stroke Impact Scale (-) • Action Research Arm Test (-) • 9 Hole Peg Test (-)
Ang et al. (2015) RCT (7) N_{Start}=26 N_{End}=25 TPS=Chronic	E: Brain computer interface + MIT-Manus robotic training C: MIT-Manus robotic training Duration: 90min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (-)
Ang et al. (2014) RCT (8) N_{Start}=22 N_{End}=21 TPS=Chronic	E1: Brain-computer interface + haptic knob (HK) robot E2: HK robot C: Standard Arm Therapy (SAT) Duration: 90min/d, 3d/wk for 6wk	E1 vs C • Fugl-Meyer Assessment (-) E2 vs C • Fugl-Meyer Assessment (-) E1 vs E2 • Fugl-Meyer Assessment (-)
Ramos-Murguialday et al. (2013) RCT (8) N_{Start}=32 N_{End}=30 TPS=Chronic	E: Brain machine interface (BMI) C: Sham BMI Duration: 5d/wk for 4wk	• Fugl Meyer Assessment (+exp) • Motor Activity Log (-) • Goal Assessment Scale (-) • Ashworth Scale (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about brain computer interfaces

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Brain computer interfaces** may not have a difference in efficacy compared to **no training** for improving motor function.	1	Young et al. 2016
1a	**Brain computer interfaces** combined with robotic training may not have a difference in efficacy compared to **robotic training alone** for improving motor function.	2	Ang et al. 2015; Ang et al. 2014
1b	**Brain computer interfaces** may produce greater improvements in motor function than **sham training**.	1	Ramos-Murguialday et al. 2013
1b	**Brain computer interfaces combined with motion tracking, electroencephalography and virtual reality** may produce greater improvements in motor function than **conventional therapy**.	1	Lin et al. 2018

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Brain computer interfaces** may not have a difference in efficacy compared to **no training** for improving dexterity.	1	Young et al. 2016

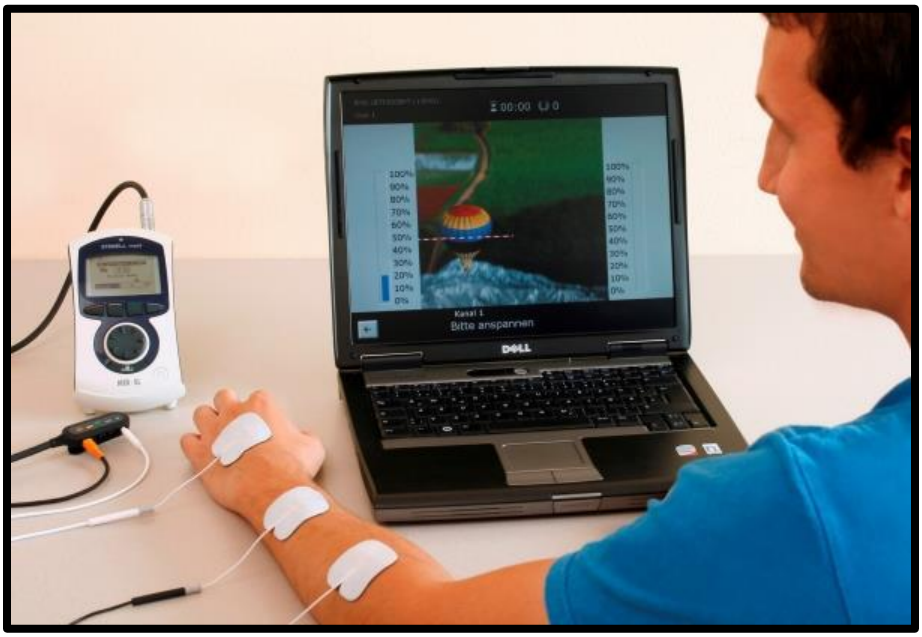
SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Brain computer interfaces** may not have a difference in efficacy **compared to sham training** for improving spasticity.	1	Ramos-Murguialday et al. 2013

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Brain computer interfaces** may not have a difference in efficacy compared to **no training** for improving activities of daily living.	1	Young et al. 2016
1b	**Brain computer interfaces** may not have a difference in efficacy compared to **sham training** for improving activities of daily living.	1	Ramos-Murguialday et al. 2013

Key points

The literature is mixed regarding brain-computer interface technology for upper limb motor rehabilitation following stroke, either on its own or combined with other therapies, but it may not be beneficial alone for other aspects of upper limb function.

EMG biofeedback



Adopted from: http://www.udbhavphysiotherapy.com/services/emg-biofeedback/10

EMG biofeedback for the treatment of hemiparesis after stroke is performed through the application of electrodes onto specific muscle groups important for a desired motor movement to monitor electrical activity during muscle contraction (Nelson, 2007). It then provides feedback of muscle activity back to the patient by conversion of myoelectrical activity into visual and/or auditory information to increase patient awareness and facilitate motor movement (Sturma et al. 2018). EMG biofeedback is particularly useful for small muscle contractions that are otherwise unnoticeable kinaesthetically or visually in the earlier stages of stroke recovery or in cases of severe paresis (Nelson, 2007).

The methodological details and results of 17 RCTs evaluating EMG biofeedback for the upper extremity motor rehabilitation are presented in Table 21.

Table 21. RCTs evaluating EMG biofeedback interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Thielbar et al. (2017) RCT (6) N_{Start} =23 N_{End} =22 TPS=Chronic	E: EMG-driven actuated glove + conventional occupational therapy C: Occupational therapy Duration: 1 hr/d, 3d/wk for 6wk	• Hand Aperture (+exp) • Action Research Arm Test (-) • Wolf Motor Function Test (-) • Fugl-Meyer Assessment (-) • Chedoke McMaster Stroke Assessment (-) • Grip/Pinch Strength (-)
Kim et al. (2017) RCT (2) N_{Start} =30 N_{End} =30 TPS=Chronic	E: EMG Biofeedback and Conventional Therapy C: Conventional Therapy	• Fugl-Meyer Assessment (-) • Manual Function Test (-) • Functional Independence Measure (-)
Garrido-Montenegro et al. (2016) RCT (8) N_{Start} =14 N_{End} =14 TPS=Chronic	E: EMG/Biofeedback + conventional occupational therapy C: Occupational therapy Duration: 1 hr/d, 4d/wk for 4wk	• Barthel Index (+exp) • Instrumental Activities of Daily Living (+exp) • Action Research Arm Test (+exp) • Motor Activity Log (+exp)
Chang-Yong et al. (2015) RCT (7) N_{Start}=44 N_{End}=40 TPS=Chronic	E: Target reaching training with biofeedback + routine therapy C: Routine therapy Duration: *Not Specified*	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) • Reach speed (+exp) • Reaching angle (+exp) • Maximum reach distance (-)
Rayegani et al. (2014) RCT (5) N_{Start}=46 N_{End}=30 TPS=Chronic	E: OT + EMG + biofeedback E2: OT + neurofeedback C: OT Duration: 40 min/d, 5d/wk for 2wk	• Jebsen Taylor Hand Test (-)
Armagan et al.(2003) RCT (7) N_{start}=27 N_{end}=27 TPS=Subacute	E: EMG/Biofeedback Therapy C: Sham EMG/biofeedback Duration: 45 min/d, 2d/wk for 5wk	• Active range of motion (+exp) • Changes in EMG surface potentials (+exp) • Brunnstrom stages (-) • Complex movement (-)
Crow et al. (1989) RCT (8) N_{start}=40 N_{end}=40 TPS=Subacute	E: EMG/Biofeedback Therapy C: Sham EMG/biofeedback Duration: *Not Specified*	• Action Research Arm test (+exp)
Basmajian et al. (1987) RCT (6) N_{start}=30 N_{end}=29 TPS=Chronic	E: EMG/Biofeedback Therapy C: Physical Therapy using neuro-facilitatory Duration: *Not Specified*	• Upper extremity function test (-) • Finger Oscillation test (-)
Inglis et al. (1984) RCT (5) N_{start}=30 TPS=Chronic	E: EMG/Biofeedback+ physiotherapy C: Physiotherapy Duration: *Not Specified*	• Active range of motion (+exp) • Brunnstrom (+exp) • Muscle strength (+exp)
Basmajian et al.(1982) RCT (6) N_{start}=37 N_{end}=37 TPS=Chronic	E: EMG/Biofeedback Therapy C: Physical Therapy using neuro-physiological approach Duration: *Not Specified*	• Upper extremity function test (-) • Min rate of manipulation test (-) • 9-hole peg test (-)

Prevo et al. (1982) RCT (3) N=28	E: EMG/Biofeedback Therapy C: Conventional Therapy Duration: 30 min/d, 2d/wk for 6wk	• Proximal and distal agonists (-)
Greenberg & Fowler (1980) RCT (5) N=20	E: EMG/Biofeedback Therapy C: Conventional Occupational Therapy Duration: *Not Specified*	• Active elbow extension (-)
Hurd et al. (1980) RCT (6) N=24 TPS=Chronic	E: Actual myofeedback C: Simulated myofeedback Duration: *Not Specified*	• Active range of motion (-) • Muscle activity (-)
Mroczek et al. (1978) RCT (5) N=9	E: EMG biofeedback C: Physical therapy Duration: *Not Specified*	• Range of Motion (-)
Lee et al. (1976) RCT (4) N=18 TPS=Acute	E1: True myofeedback E2: Placebo myofeedback C: No myofeedback with conventional training. Duration: *Not Specified*	• Peak amplitude (-)
EMG biofeedback combined with additional interventions		
Cordo et al. (2013) RCT (6) N_{Start}=46 N_{End}=43 TPS=Chronic	E1: AMES robot + torque biofeedback E2: AMES robot + EMG biofeedback Duration: 30 min/d, 3d/wk for 10 wk	• Fugl Meyer Score (-) • Flexion torque strength (+exp) • Extension strength (-) • Box and Block Test (-) • Stroke Impact Scale (-)
Hemmen & Seelen (2007) RCT (7) N_{start}=27 N_{end}=27 TPS=Subacute	E: EMG biofeedback + mental practice C: Conventional electrostimulation Duration: 30 min/d, 5d/wk for 3 mo	• Fugl-Meyer Score (-) • Action Research Arm test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about EMG biofeedback

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**EMG biofeedback** may not have a difference in efficacy when compared to **sham feedback or conventional therapy** for improving motor function.	8	Thielbar et al. 2017; Kim et al. 2017; Garrido-Montenegro et al. 2016; Chang-Yong et al. 2015; Rayegani et al. 2014; Crow et al. 1989; Basmajian et al. 1987; Basmajian et al. 1982
1b	**EMG biofeedback combined with arm robotics** may not have a difference in efficacy when compared to **torque biofeedback combined with arm robotics** for improving motor function.	1	Cordo et al. 2013
1b	**EMG biofeedback combined with mental practice** may not have a difference in efficacy when compared to **conventional electrostimulation** for improving motor function.	1	Hemmen and Seelen, 2007

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**EMG biofeedback** may not have a difference in efficacy when compared to **sham feedback or conventional therapy** for improving dexterity.	1	Basmajian et al. 1982
1b	**EMG biofeedback combined with arm robotics** may not have a difference in efficacy when compared to **torque biofeedback combined with arm robotics** for improving dexterity.	1	Cordo et al. 2013

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**EMG biofeedback** may not have a difference in efficacy compared to **sham feedback or conventional therapy** for improving spasticity.	2	Prevo et al.1982; Greenberg and Fowler, 1980

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **EMG biofeedback** to improve range of motion when compared to **sham feedback or conventional therapy**.	4	Armagan et al. 2003; Inglis et al. 1984; Greenberg and Fowler, 1980; Mroczek et al. 1978

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **EMG biofeedback** to improve performance on measures of stroke severity when compared to **sham feedback or conventional therapy**.	2	Armagan et al. 2003; Inglis et al. 1984

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **EMG biofeedback** to improve performance of activities of daily living when compared to **sham feedback or conventional therapy**.	3	Thielbar et al. 2017; Kim et al. 2017; Garrido-Montenegro et al. 2016
1b	**EMG biofeedback combined with arm robotics** may not have a difference in efficacy when compared to **torque biofeedback combined with arm robotics** to improve performance of activities of daily living.	1	Cordo et al. 2013

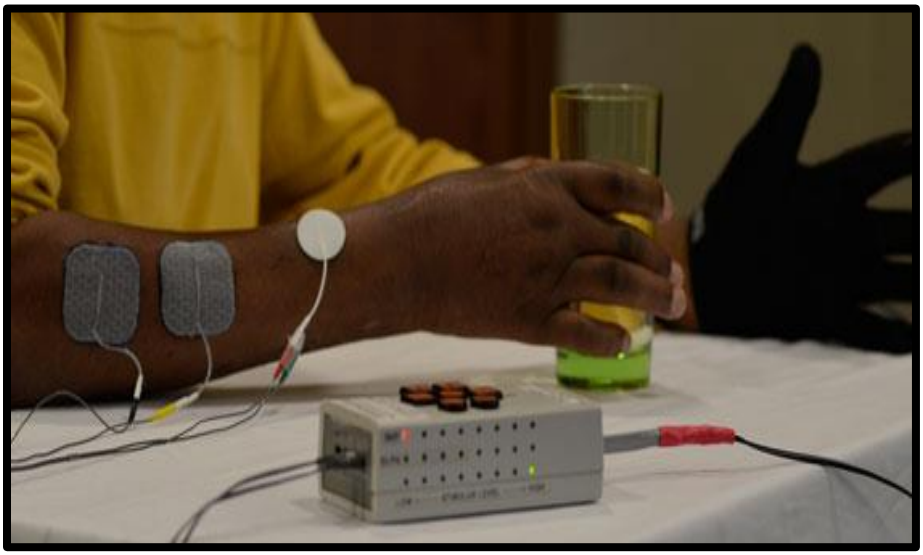
MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **EMG biofeedback** to improve muscle strength when compared to **sham feedback or conventional therapy**.	2	Thielbar et al. 2017; Inglis et al. 1984
1b	There is conflicting evidence about the effect of **torque biofeedback combined with arm robotics** to improve muscle strength when compared to **EMG biofeedback combined with arm robotics**.	1	Cordo et al. 2013

Key points

The literature is mixed regarding EMG biofeedback alone for upper limb rehabilitation following stroke, however it may not be beneficial when combined with other therapy approaches.

Sensorimotor stimulation

Neuromuscular electrical stimulation (NMES)



Adopted from: http://fescenter.org/patient-resources/current-clinical-trials/stroke-programs/hand-function-control-2/hand-function-control/

Neuromuscular electrical stimulation (NMES) is a technique used to generate muscle contractions in regions affected by hemiparesis by stimulating lower motor neurons involved in muscle movement through transcutaneous application of electrical currents (Monte-Silva et al. 2019; Allen & Goodman 2014). Three forms of NMES are available:

1. Cyclic NMES in which a muscle is repetitively stimulated at near maximum contraction on a pre-set schedule and patient participation is passive (Nascimento et al. 2013);
2. Electromyography (EMG) triggered NMES, a target muscle is directly controlled or triggered by volitional EMG activity from the target or a different muscle to elicit a desired stimulation (Monte-Silva at al. 2019);
3. Functional electrical stimulation (FES), which refers to the application of NMES to assist voluntary during a functional task (Eraifej et al. 2017).

A total of 67 unique RCTs were found for using NMES to enhance upper extremity motor rehabilitation.

Interventions in 11 RCTs were cyclic NMES compared to sham stimulation or conventional rehabilitation (Tilkici et al. 2017; Baygutalp et al. 2014; De Jong et al. 2013; Malhotra et al. 2013; Sahin et al. 2012; Lin and Yan, 2011; Mann et al. 2005; Powell et al. 1999; Chae et al. 1998; King et al. 1996; Faghri et al. 1994). RCTs also looked at the combination of cyclic NMES with: robotics (Barker et al. 2017; Miyasaka et al. 2016; Lee et al. 2015; Hayward et al. 2013), and repetitive task training (Gharib et al. 2014).

10 RCTs looked at EMG-triggered NMES to sham stimulation or conventional rehabilitation (Park et al. 2017; Kwakkel et al. 2016; Dorsch et al. 2014; Bhatt et al. 2007; Gabr et al. 2005; Kimberley et al. 2004; Cauraugh and Kim, 2003; Cauraugh et al. 2000; Francisco et al. 1998; Bowman et al. 1979). RCTs looked at the combination of EMG-triggered NMES with: robotics (Qian et al. 2017; Hu et al. 2015; Barker et al. 2008), mirror therapy (Schick et al. 2017; Kojima et al. 2014), or a splint (Shindo et al. 2011).

14 RCTs looked at the effects of FES compared to sham stimulation or conventional rehabilitation (Demir et al. 2018; Pan et al. 2018; Carda et al. 2017; Marquez-Chin et al. 2017; Yuzer et al. 2017; Shimodozono et al. 2014; Karakus et al. 2013; Mangold et al. 2009; Hara et al. 2008; Thrasher et al. 2008; Hara et al. 2006; Ring and Rosenthal, 2005; Popovic et al. 2003; Faghri and Rodgers, 1997). RCTs looked at the combination of FES with: mirror therapy (Mathieson et al. 2018; Kim et al. 2015), botulinum toxin (Weber et al. 2010), action observation paired with brain computer interface (Kim et al. 2016), bilateral arm training (Chan et al. 2009), and task-oriented therapy (Jonsdottir et al. 2017).

Nine RCTs looked at the effect of different NMES techniques compared to each other (Jeon et al. 2017; Knutson et al. 2016; Wilson et al. 2016; Boyaci et al. 2013; You et al. 2013; Knutson et al. 2012; Chae et al. 2009; De Kroon and Ijzerman, 2008; Hemmen and Seelen, 2007)

Three RCTs looked at differing intensity of NMES (Page et al. 2012; Hsu et al. 2010; Kowalczewski et al. 2007), high versus low frequency cyclic NMES (Doucet and Griffin, 2013), and early versus delayed FES (Popovic et al. 2004).

The methodological details and results of all 67 RCTs are presented in table 22.

Table 22. Summary of RCTs evaluating NMES for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Cyclic NMES versus conventional therapy		
Tilkici et al. (2017) RCT (6) N_{Start} =40 N_{End} =40 TPS=Chronic	E: Neuromuscular Electrical Stimulation C: Conventional Therapy Duration: 30min/d, 5d/wk for 3wk	• Modified Ashworth Scale (+exp) • Wrist Extension (+exp) • Brunnstrom's Recovery Stages (-) • Modified Ashworth Scale (-) • Fugl-Meyer Assessment (-) • Duruoz Hand Index (-) • Functional Independence Measure (-)
Baygutalp et al. (2014) RCT (5) N_{Start}=30 N_{End}=30 TPS=Chronic	E: NMES + conventional therapy C: Conventional therapy Duration: 60min/d, 5d/wk for 3wk	• Modified Ashworth Scale (-) • Barthel Index (-) • Brunnstrom's Recovery Stages (-)
De Jong et al. (2013) RCT (8) N_{start}=46 N_{end}=46 TPS=Subacute	E: Arm stretch positioning + NMES C: Sham stretch positioning + Sham NMES Duration: 45 min (2x/d), 5d/wk, for 8 wk	• Modified Ashworth Scale (-)
Malhotra et al. (2013) RCT (5) N_{Start}=90 N_{End}=65 TPS=Acute	E: NMES C: Conventional therapy Duration: 30 min (2x/d), 5d/wk for 6 wk	• Passive Range of Motion (-)
Sahin et al. (2012) RCT (5) N_{start}=42 N_{end}=38 TPS=Chronic	E: Stretching + NMES C: Stretching Duration: 5d/wk for 4wk	• Modified Ashworth Scale (+exp)
Lin & Yan (2011) RCT (6) N_{stat}=46 N_{end}=37 TPS=Acute	E: Cyclic NMES + standard rehabilitation C: Standard rehabilitation Duration: 30 min/d, 5d/wk for 3 wk	• Fugl-Meyer Assessment (+exp) • Barthel Index (+exp)
Mann et al. (2005) 5 (RCT) N_{start}=22 N_{end}=22 TPS=Chronic	E: Neuromuscular Electrical Stimulation C: Passive Extension Exercises Duration: 10-30min (2x per day) for 12wk	• Action Research Arm Test (+exp)
Powell et al. (1999) RCT (7) N_{start}=60 N_{end}=48 TPS=Subacute	E: Cyclic electrical stimulation + standard rehabilitation C: Standard rehabilitation Duration: 30 min (3x per day), 3d/wk for 8 wk	• Action Research Arm test (+exp)
Chae et al. (1998) RCT (6) N_{start}=46 N_{end}=28 TPS=Subacute	E: Cyclic NMES C: Sham stimulation + routine rehabilitation Duration: 1 hr/d, 5d/wk for 3 wk	• Fugl-Meyer Assessment (+exp)
King et al. (1996) RCT (4) N_{start}=21 N_{end}=NR TPS=Chronic	E: NMES C: Passive stretch Duration: *Not reported*	• Tone reduction (+exp)

Faghri et al. (1994) RCT (4) N_{start}=26 N_{end}=NR TPS=NR	E: Cyclic NMES + conventional therapy C: Conventional Therapy Duration: 1.5-6h/d for 6wk	• Arm tone (+exp)
Cyclic NMES combined with robotics		
Barker et al. (2017) RCT (7) N_{Start} =50 N_{End} =38 TPS=Subacute	E1: SMART Arm Training + Outcome-Triggered Electrical Stimulation + Conventional Therapy E2: SMART Arm Training + Conventional Therapy C: Conventional Therapy Duration: 60min/d, 5d/wk for 4wk	E1 vs E2 vs C • Motor Assessment Scale (-) • Modified Ashworth Scale (-) • Triceps Strength (-)
Miyasaka et al. (2016) RCT (5) N_{Start}=30 N_{End}=30 TPS=Subacute	E: NMES + robotic training C: Robotic training Duration: 1 hr/d, 5d/wk for 2 wk	• Fugl-Meyer Assessment (-) • Range of Motion (-)
Lee et al. (2015) RCT (8) N_{Start}=39 N_{End}=39 TPS=Chronic	E: NMES + robotic therapy C: Sham NMES + robotic therapy Duration: 90-100min/d, 5d/wk for 4wk	• Modified Ashworth Scale (+exp) • Wolf Motor Function Test (+exp) • Stroke Impairment Scale (+exp) • Fugl-Meyer Assessment (-) • Motor Activity Log (-)
Hayward et al. (2013) RCT (6) N_{start}=8 N_{end}=8 TPS=Acute	E: SensoriMotor Active Rehabilitation Training (SMART) with outcome trigger electrical stimulation (OT-stim) C: SensoriMotor Active Rehabilitation Training (SMART) Duration: 1 hr/d, 5d/wk for 4 wk	• Motor Assessment Scale (-) • Upper Arm Function (-)
Cyclic NMES with repetitive task training		
Gharib et al. (2014) RCT (9) N_{Start}=40 N_{End}=40 TPS=Chronic	E: Cyclic NMES (20Hz) + repetitive task training C: Sham electrical stimulation + repetitive task practice Duration: 1 hr/d, 4d/wk for 8 wk	• Modified Ashworth Scale (+exp) • Jebsen Taylor Hand Function Test (+exp) • Range of Motion (+exp)
EMG-triggered NMES compared to sham stimulation		
Park et al. 2017 RCT (2) N_{Start} =40 N_{End} =32 TPS=NR	E: Mental Practice combined with Electromyography-Triggered Electrical Stimulation C: Conventional Rehabilitation Program Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp)
Kwakkel et al. (2016) RCT (7) N_{Start}=159 N_{End}=159 TPS=Acute	E1: EMG-NMES (unfavourable prognosis) E2: Modified constraint-induced movement therapy (favourable prognosis) C1: Unfavourable prognosis based on preservation or return of voluntary finger extension early after stroke (received usual care) C2: Favourable prognosis based on preservation or return of voluntary finger extension early after stroke (received usual care) Duration: 1 hr/d, 3d/wk for 3 wk	E1 vs C1 • Action Research Arm Test: (-) • Fugl-Meyer Assessment: (-) • Motricity Index: (-) • Stroke Impact Scale: (-) • Wolf Motor Function Test: (-) • Motor Activity Log: (-) E2 vs C2 • Action Research Arm Test: (+exp_2) • Fugl-Meyer Assessment: (-) • Motricity Index: (-) • Stroke Impact Scale: (+exp_2) • Wolf Motor Function Test: (-) • Motor Activity Log: (-)
Dorsch et al. (2014) RCT (7) N_{Start}=33 N_{End}=30	E: EMG-triggered NMES C: Usual therapy Duration: 30 min/d, 6d/wk for 8wk	• Modified Ashworth Scale (-) • Manual Muscle Test (-)

TPS=Acute		
Bhatt et al. (2007) RCT (3) N_{start}=20 N_{end}=18 TPS=Chronic	E1: EMG-triggered NMES E2: Tracking training E3: EMG-triggered NMES + tracking training Duration: 1 hr/d, 5d/wk, for 2 wk	E1 vs E2 vs E3 • Jebson Taylor Hand Function Test (-) • Box & Block Test (-)
Gabr et al. (2005) RCT (4) N_{start}=12 N_{end}=12 TPS=Chronic	E: EMG-triggered NMES C: Home exercise Duration: 45 min/d, 3d/wk for 4 wk	• Fugl Meyer Score (+exp) • Action Research Arm Test (-)
Kimberley et al. (2004) RCT (7) N_{start}=16 N_{end}= 16 TPS=Chronic	E: EMG-triggered NMES C: Sham Duration: 3hr/d, 5d/wk for 3 wk	• Box & Block test (+exp) • Motor Activity Log (+exp) • Jebsen Taylor Hand Function Test (+exp)
Cauraugh and Kim (2003) RCT (5) N_{start}=34 N_{end}=31 TPS=Chronic	E1: EMG-triggered NMES + blocked practice E2: EMG-triggered NMES + random practice C: Conventional therapy Duration : 90 min/d, 2d/wk (24hr in between) for 2 wk	E1/E2 vs C • Box and Block Test (+exp_1, +exp_2) • Sustained wrist/finger contraction (+exp_1, +exp_2) E1 vs E2 • Box and Block Test (-) • Sustained wrist/finger contraction (-)
Cauraugh et al. (2000) RCT (4) N_{start}=11 N_{end}=11 TPS=Chronic	E: EMG-triggered NMES + passive range of motion + stretching exercises C: Passive range of motion + stretching exercises Duration: 30 min/d, 4d/wk, for 3 wk	• Box and Block test (+exp) • Motor Assessment scale (-) • Fugl-Meyer upper extremity (-)
Francisco et al. (1998) RCT (3) N_{start}=9 N_{end}=9 TPS=Acute	E: EMG-triggered NMES + standard therapy C: Conventional Therapy Duration: 30 min (2x per day), 5d/wk for 4 wk	• Fugl-Meyer Assessment (+exp) • Functional Independence Measure (+exp)
Heckman et al. (1997) RCT(4) N_{start}=28 N_{end}=28 TPS=Subacute	E: EMG-triggered ES + standard therapy C: Standard therapy Duration: 5d/wk for 4wk	• Hand extension (+exp) • Muscle tone (+exp)
Bowman et al. (1979) RCT (3) N_{start}=30 N_{end}=NR TPS=NR	E: Conventional therapy + positional feedback electrical stimulation therapy C: Conventional Therapy Duration: 30min (2x per day), 5d/wk for 4wk	• Range of motion (+exp)
EMG-triggered NMES combined with robotics		
Qian et al. (2017) RCT (6) N_{Start} =24 N_{End} =24 TPS=Acute-Subacute	E: Electromyography-Driven Neuromuscular Electrical Stimulation-Robot Arm C: Conventional Therapy Duration: 40min, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp) • Action Research Arm Test (-) • Functional Independence Measure (-)
Hu et al. (2015) RCT (6) N_{Start}=26 N_{End}=26 TPS=Chronic	E: EMG-driven NMES robot C: EMG-driven robot Duration: 30 min/d, 4d/wk for 5 wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (+exp) • Modified Ashworth Scale (-)
Barker et al. (2008) RCT (7) N_{start}=33 N_{end}=30	E1: SMART Arm + EMG-triggered NMES E2: SMART Arm C: Conventional therapy	E1/E2 vs C • Modified Ashworth Scale: (+exp_1, +exp_2)

TPS=Chronic	Duration: 1 hr/d, 3d/wk for 4 wk	
EMG-triggered NMES with mirror therapy		
Schick et al. (2017) RCT (7) N_{Start} =33 N_{End} =32 TPS=Subacute	E: Bilateral Electromyography-Neuromuscular Electrical Stimulation with Mirror Therapy C: Electromyography-Neuromuscular Electrical Stimulation Duration: 30min/d, 5d/wk for 3wk	• Fugl-Meyer Assessment (-) • Rivermead Assessment of Somatosensory Performance (-) • Box and Block Test (-) • Barthel Index (-)
Kojima et al. (2014) RCT crossover (7) N_{Start}=13 N_{End}=13 TPS=Subacute	E: Mirror therapy + EMG-triggered NMES first C: Mirror therapy + EMG-triggered NMES delayed Duration: 30 min/d, 4d/wk for 8 wk	• Fugl-Meyer Assessment (+exp) • Hand range of Motion (+exp)
EMG-triggered NMES with splint		
Shindo et al. (2011) RCT (6) N_{start}=24 N_{end}=20 TPS=Subacute	E: EMG-triggered NMES + splint C: Splint Duration: 45 min/d, 3d/wk for 3 wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (-) • Action Research Arm Test (+exp)
FES versus conventional therapy		
Demir et al. 2018 RCT (4) N_{Start} =29 N_{End} =17 TPS=Chronic	E: Functional Electrical Stimulation and Conventional Physiotherapy C: Conventional Physiotherapy Duration: 15-45min (2x per day), 5d/wk for 8wk	• Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-) • Motor Activity Log-28 (-) • Jebsen-Taylor Hand Function Test (-)
Pan et al. 2018 RCT (6) N_{Start} =12 N_{End} =12 TPS=Subacute	E: Fuinctional Electrical Stimulation C: Sham Electrical Stimulation Duration: 40min/d, 2d/wk for 8wk	• Fugl-Meyer Assessment (-)
Carda et al. (2017) RCT-Crossover (7) N_{Start} =11 N_{End} =11 TPS=Chronic	E: Functional Electrical Stimulation C: Conventional Therapy Duration: 90min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp) • Wolf Motor Function Test (-) • Resistance to Passive Movement Scale (-)
Marquez-Chin et al. (2017) RCT (7) Secondary Analysis N_{Start} =21 N_{End} =21 TPS=Subacute	E: Functional Electrical Stimulation C: Conventional Therapy Duration: 1h/d, 5d/wk for 8wk	• Functional Independence Measure (+exp) • Fugl-Meyer Assessment (+exp)
Yuzer at al. 2017 RCT (6) N_{Start} =30 N_{End} =30 TPS=Subacute	E: Functional Electrical Stimulation and Conventional Therapy C: Conventional Therapy Duration: 30min/d, 5d/wk for 4wk	• Barthel Index (+exp) • Brunnstrom Stages (-) • Upper Extremity Performance Test (-)
Shimodozono et al. (2014) RCT (8) N_{Start}=27 N_{End}=24 TPS= Subacute	E1: Continuous NMES + repetitive facilitative exercise E2 Repetitive facilitative exercise C: Conventional therapy Duration: 40 min/d, 5d/wk for 4 wk	• Fugl-Meyer Assessment (+exp$_2$) • Elbow extension (+exp$_2$) • Shoulder flexion (-) • Wrist flexion (-)
Karakus et al. (2013) RCT (8) N_{Start}=28 N_{End}=28 TPS= Subacute	E: FES + standard rehabilitation C: Standard rehabilitation Duration: 30min/d, 5d/wk for 2wk	• Brunnstrom recovery stages (+exp) • Motricity Index (+exp) • Modified Ashworth Scale (-)
Mangold et al. (2009) RCT (5) N_{start}=23	E: FES C: Conventional therapy Duration: 1 hr/d, 3d/wk for 4 wk	• Barthel Index (-) • Chedoke McMaster Stroke Assessment (-)

N_{end}=23 TPS=Subacute		
Hara et al. (2008) RCT (5) N_{start}=20 N_{end}=20 TPS=Chronic	E: FES C: Conventional therapy Duration: 45 min/d, 6d/wk for 4 wk	• Range of motion (+exp) • Modified Ashworth Scale (+exp)
Thrasher et al. (2008) RCT (5) N_{start}=21 N_{end}=19 TPS=Subacute	E: FES + conventional therapy C: Conventional therapy Duration: 30 min/d, 4d/wk for 12 wk	• Rehabilitation Engineering Laboratory Hand Function Test (+exp)
Hara et al. (2006) RCT (4) N_{start}=14 N_{end}=14 TPS=Chronic	E: FES C: Conventional therapy Duration: 1 hr/d, 2d/wk for 4 mo	• Modified Ashworth Scale (-) • Range of Motion (+exp)
Ring & Rosenthal (2005) RCT(6) N_{start}=22 N_{end}=NR TPS=Subacute	E: Neuroprosthetic FES C: Conventional therapy Duration: 25 min/d, 3d/wk for 5 wk	• Modified Ashworth Scores (+exp) • Box & Block test (+exp) • Jebsen Taylor Hand Function test (+exp)
Popovic et al. (2003) RCT (6) N_{start}=28 N_{end}=28 TPS=Subacute	E: FES C: Standard therapy Duration: 30 min/d, 7d/wk for 3 wk	• Upper extremity performance test (+exp)
Faghri & Rodgers (1997) RCT (4) N_{start}=26 N_{end}=26 TPS=Acute	E: FES + conventional therapy C: Conventional therapy Duration: 6 hr/d, 6d/wk for 6 wk	• Range of motion (+exp) • Shoulder muscle tone (+exp)
FES combined with additional therapies		
Mathieson et al. (2018) RCT (8) N_{Start} =50 N_{End} =47 TPS=Acute	E1: Functional Electrical Stimulation E2: Mirror Therapy E3: Functional Electrical Stimulation with Mirror Therapy Duration: 30min (2x per day), 5d/wk for 3wk	E1 vs E2 • Action Research Arm Test (+exp) • Fugl-Meyer Assessment (+exp) • Nottingham Extended Activities of Daily Living Test (-) • Functional Independence Measure (-)
Jonsdottir et al. 2017 RCT (5) N_{Start} =82 N_{End} =45 TPS=Subacute	E: Myoelectric Continuous Control of Functional Electrical Stimulation Task-Oriented Therapy C: Task Oriented Therapy Duration: 45min/d, 5d/wk for 5-6wk	• Action Research Arm Test (-) • Fugl-Meyer Assessment (-) • Disability of the Arm, Shoulder, and Hand Questionnaire (-)
Kim et al. (2016) RCT (7) N_{Start} =34 N_{End} =30 TPS=Chronic	E: FES with Action observation training and brain computer interface C: Conventional training Duration: 30min, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp) • Modified Barthel Index (+exp) • Wrist Flexion (+exp)
Kim et al. (2015) RCT (5) N_{Start}=33 N_{End}=29 TPS=Chronic	E1: FES with biofeedback + mirror therapy E2: FES + mirror therapy C: Conventional rehabilitation Duration: 30 min/d, 5d/wk for 4 wk	E1 vs C • Functional Independence Measure (+exp) • Jebsen Taylor Hand test (+exp) • Manual Muscle Test (+exp) • Box and Block Test (+exp) • Wrist Extension (+exp) • Grip strength (-) • Modified Ashworth Scale (-) E1 vs E2 • Functional Independence Measure (-) • Jebsen Taylor Hand test (+exp)

		• Manual Muscle Test (+exp) • Box and Block Test (+exp) • Wrist Extension (+exp) • Grip strength (+exp) • Modified Ashworth Scale (-)
Weber et al. (2010) RCT (7) N_{start}=23 N_{end}=23 TPS=Chronic	E: FES + botulinum toxin-A + home based exercise program C: Botulinum toxin-A + home-based exercise program Duration: 1 hr/d, 5d/wk for 4 wk	• Motor Activity Log (-) • Action Research Arm Test (-)
Chan et al. (2009) RCT (7) N_{start}=20 N_{end}=20 TPS=Chronic	E: Bilateral arm training + FES C: Bilateral arm training + sham FES Duration: 70 min/d, 3d/wk for 5 wk	• Fugl-Meyer Assessment (+exp) • Functional test for the Hemiplegic Upper Extremity (+exp) • Modified Ashworth Scale (-)
Alon et al. (2007) RCT (5) N_{start}=15 N_{end}=15 TPS=Subacute	E: FES + task specific training C: Task specific training Duration: 30 min(2x/d), 5d/wk for 12 wk	• Box and Block Test (+exp) • Jebsen-Taylor light object lift (+exp) • Fugl-Meyer Assessment (+exp)
NMES techniques versus each other		
Jeon et al. (2017) RCT (5) N_{Start} =20 N_{End} =20 TPS=Subacute	E: EMG-triggered NMES C: FES Duration: 30min, 5d/wk for 4wk	• Fugl-Meyer Assessment (-)
Knutson et al. (2016) RCT (5) N_{Start} =80 N_{End} =64 TPS=Chronic	E1: Functional Electrical Stimulation E2: Cyclic NMES Duration: 2hrs, 7d/wk for 6 wk	• Fugl-Meyer Assessment (-) • Arm Motor Abilities Test (-) Box and Block Test (+exp)
Wilson et al. (2016) RCT (6) N_{Start} =122 N_{End} =96 TPS=Subacute	E1: Cyclic Neuromuscular Electrical Stimulation E2: Electromyographically-triggered Neuromuscular Electrical Stimulation E3: Sensory Stimulation Duration: 40 min (2x/d), 5d/wk for 8 wk	• Fugl-Meyer Assessment (-) • Modified Arm Motor Ability Task (-)
Boyaci et al. (2013) RCT (7) N_{Start}=31 N_{End}=31 TPS=Chronic	E1: EMG-triggered NMES E2: Cyclic NMES C: Control Duration: 45 min/d, 5d/wk for 3 wk	E1 vs C • Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp) • Spasticity in wrist flexor (-) • Spasticity in finger flexor (-) • Range of Motion in active wrist extension (+exp) • Range of Motion in active metacarpophalangeal joint extension (+exp) • Grip strength (+exp) E2 vs C • Fugl-Meyer Assessment (+exp$_2$) • Motor Activity Log (-) • Spasticity in wrist flexor (+exp$_2$) • Spasticity in finger flexor (-) • Range of Motion in active wrist extension (+exp$_2$) • Range of Motion in active metacarpophalangeal joint extension (-) • Grip strength (-) E1 vs E2 • Fugl-Meyer Assessment (-) • Motor Activity Log (-) • Spasticity in wrist flexor (-) • Spasticity in finger flexor (-)

		• Range of Motion in active wrist extension (-) • Range of Motion in active metacarpophalangeal joint extension (-) • Grip strength (-)
You et al. (2013) RCT (7) N_{Start}=18 N_{End}=16 TPS=Chronic	E: Mental training + EMG stimulation C: FES Duration: 40 min/d, 2d/wk for 4wk	• Range of Motion (-) • Modified Ashworth Scale (-) • Fugl-Meyer Assessment (+exp) • Motor Activity Log (-) • Barthel Index (-)
Knutson et al. (2012) RCT (6) N_{start}=21 N_{end}=21 TPS=Subacute	E1: Contralaterally controlled FES E2: Cyclic NMES Duration: 90 min/d, 3d/wk for 4 wk	• Maximum finger extension angle (-) • Tracking error (% of AROM) (-) • Fugl-Meyer Assessment (-) • Box and Block Test (-) • Arm Motor Abilities Test Score (-)
Chae et al. (2009) RCT (8) N_{start}=26 N_{end}=26 TPS=Chronic	E1: EMG-triggered NMES E2: Cyclic NMES Duration: 1 hr/d, 7d/wk for 6 wk	• Arm Motor Ability Test (-)
De Kroon & Ijzerman (2008) RCT (7) N_{start}=22 N_{end}=22 TPS=Chronic	E1: EMG-triggered NMES E2: Cyclic NMES Duration: 30 min/d, 3d/wk for 6 wk	• Action Research Arm test (-) • Grip Strength (-) • Fugl-Meyer Score (-) • Motricity Index (-)
Hemmen & Seelen (2007) RCT (7) N_{start}=27 N_{end}=27 TPS=Subacute	E1: EMG-triggered NMES E2: Cyclic NMES Duration: 30 min/d, 5d/wk for 3mo	• Fugl-Meyer Assessment (-) • Action Research Arm test (-)
Low versus high intensity NMES studies		
Page et al. (2012) RCT (7) N_{start}=32 N_{end}=32 TPS=Chronic	E1: 30 minutes of electrical stimulation therapy with repetitive task specific practice E2: 60 minutes of electrical stimulation therapy with repetitive task specific practice E3: 120 minutes of electrical stimulation therapy with repetitive task specific practice Duration: 30 min OR 60 min OR 120 min, 5d/wk for 8 wk.	E3 vs. E2/E1 • Fugl-Meyer Assessment (+exp_3) • Arm Motor Ability Test (+exp_3) • Action Research Arm Test (+exp_3)
Hsu et al. (2010) RCT (6) N_{start}=66 N_{end}=66 TPS=Acute	E1: High intensity cyclic NMES (60 min) E2: Low intensity cyclic NMES (30 min) C: No treatment Duration: 30/60 min, 5d/wk for 4 wk	E1/E2 vs C • Fugl Meyer Assessment (+exp_1, +exp_2) • Action Research Arm Test (+exp_1, +exp_2) • Grasp (+exp_1, +exp_2) • Grip (+exp_1, +exp_2) • Pinch (+exp_1, +exp_2) • Gross Movement (+exp_1, +exp_2) E1 vs E2 • Fugl Meyer Assessment (-) • Action Research Arm Test (-) • Grasp (-) • Grip (-) • Pinch (-) • Gross Movement (-)
Kowalczewski et al. (2007) RCT (6) N_{start}=19 N_{end}=18 TPS=Subacute	E1: High intensity FES exercise therapy (60 min) E2: Low intensity FES exercise therapy (15 min) Duration: 15/60 min, 5d/wk for 3 wk	• Wolf Motor Function Test (+exp_1) • Motor Activity Log (-) • Fugl-Meyer Assessment (-)

High versus low frequency cyclic NMES		
Doucet and Griffin (2013) RCT (5) N_{Start}=16 N_{End}=16 TPS=Chronic	E1: High frequency cyclic NMES (40Hz) E2: Low frequency cyclic NMES (20Hz) Duration: 1 hr/d, 4d/wk for 4 wk	• Lateral pinch strength (+exp) • Minnesota Manual Dexterity Test (+exp) • Endurance of thumb adduction (+exp)
Early versus delayed FES		
Popovic et al. (2004) RCT (6) N_{start}=41 N_{end}=32 TPS=Acute	E: Early (acute) FES C: Delayed (chronic) FES Duration: 30 min/d, 7d/wk for 3 wk	• Upper extremity performance test (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about NMES

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Cyclic NMES** may produce greater improvements in motor function than **sham stimulation or conventional therapy**.	7	Tilkici et al. 2017; Baygutalp et al. 2014; Inobe et al. 2013; Lin and Yan 2011; Mann et al. 2005; Powell et al. 1999; Chae et al. 1998
1a	**Cyclic NMES combined with arm robotics** may not have a difference in efficacy when compared to **arm robotics on their own or conventional therapy** for improving motor function.	3	Miyasaka et al. 2016; Lee et al. 2015; Hayward et al. 2013
1b	**Cyclic NMES combined with repetitive task training** may produce greater improvements in motor function than **repetitive task training alone**.	1	Gharib et al. 2014
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving motor function.	7	Park et al. 2017; Kwakkel et al. 2016; Bhatt et al. 2007; Gabr et al. 2005; Kimberley et al. 2004; Cauraugh et al. 2000; Francisco et al. 1998
1a	**EMG-triggered NMES combined with arm robotics** may produce greater improvements in motor function than **arm robotics on their own or conventional therapy**.	2	Qian et al. 2017; Hu et al. 2015
1a	There is conflicting evidence about the effect of **EMG-triggered NMES combined with mirror therapy** to improve motor function when compared to **mirror therapy on its own**.	2	Schick et al. 2017; Kojima et al. 2014
1b	**EMG-triggered NMES combined with splints** may produce greater improvements in motor function than **splints on their own**.	1	Shindo et al. 2011
1a	There is conflicting evidence about the effect of **FES** to improve motor function when compared to **sham stimulation or conventional therapy**.	11	Demir et al. 2018; Pan et al. 2018; Carda et al. 2017; Maquez-Chin et al. 2017; Yuzer et al. 2017; Shimodozono et al. 2014; Karakus et al. 2013; Mangold et al. 2009; Thrasher et al. 2008; Ring and Rosenthal, 2005; Popovic et al. 2003
1b	**FES** may produce greater improvements in motor function than **mirror therapy**.	1	Mathieson et al. 2018
2	There is conflicting evidence about the effect of **FES combined with task-specific training** to improve motor function when compared to **task-specific training**.	2	Jonsdottir et al. 2017; Alon et al. 2007
2	**FES combined with biofeedback and mirror therapy** may produce greater improvements in motor function than **FES combined with mirror therapy or conventional therapy**.	1	Kim et al. 2015
1b	**FES combined with botulinum toxin A and a home exercise program** may not have a difference in	1	Weber et al. 2010

	efficacy when compared to **botulinum toxin A combined with a home exercise program** for improving motor function.		
1b	**Bilateral arm training combined with FES** may produce greater improvements in motor function than **bilateral arm training combined with sham FES**.	1	Chan et al. 2009
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **cyclic NMES** for improving motor function.	3	Wilson et al. 2016; Boyaci et al. 2013; De Kroon et al. 2008
2	**EMG-triggered NMES** may not have a difference in efficacy when compared to **FES** for improving motor function.	1	Jeon et al. 2013
1b	**FES** may not have a difference in efficacy when compared to **cyclic NMES** for improving motor function.	2	Knutson et al. 2016; Knutson et al. 2012

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**EMG-triggered NMES** may produce greater improvements in dexterity than **sham stimulation or conventional therapy**.	4	Bhatt et al. 2007; Kimberley et al. 2004; Cauraugh and Kim 2003; Cauraugh et al. 2000
1b	**EMG-triggered NMES combined with mirror therapy** may not have a difference in efficacy when compared to **mirror therapy on its own** for improving dexterity.	1	Schick et al. 2017
1b	**FES** may produce greater improvements in dexterity than **sham stimulation or conventional therapy**.	1	Ring and Rosenthal, 2005
2	**FES combined with task-specific training** may produce greater improvements in dexterity than **task-specific training**.	1	Alon et al. 2007
2	**FES combined with biofeedback and mirror therapy** may produce greater improvements in dexterity than **FES combined with mirror therapy or conventional therapy**.	1	Kim et al. 2015
1b	There is conflicting evidence about the effect of **FES** to improve dexterity when compared to **cyclic NMES**.	2	Knutson et al. 2016; Knutson et al. 2012

PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**EMG-triggered NMES combined with mirror therapy** may not have a difference in efficacy when compared to **mirror therapy on its own** for improving proprioception.	1	Schick et al. 2017

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **cyclic NMES** to improve spasticity when compared to **sham stimulation or conventional therapy**.	6	Tilkici et al. 2017; Baygutalp et al. 2014; De Jong et al. 2013; Sahin et al. 2012; King et al. 1996; Faghri et al. 1994
1a	There is conflicting evidence about the effect of **cyclic NMES combined with arm robotics** to improve spasticity when compared to **arm robotics on their own or conventional therapy**.	2	Barker et al. 2017; Lee et al. 2015
1b	**Cyclic NMES combined with repetitive task training** may produce greater improvements in spasticity than **repetitive task training alone**.	1	Gharib et al. 2014
2	**EMG-triggered NMES** may produce greater improvements in spasticity than **sham stimulation or conventional therapy**.	1	Cauraugh and Kim, 2003
1a	There is conflicting evidence about the effect of **EMG-triggered NMES combined with arm robotics** to improve spasticity when compared to **arm robotics on their own or conventional therapy**.	3	Qian et al. 2017; Hu et al. 2015; Barker et al. 2008
1a	There is conflicting evidence about the effect of **FES** to improve spasticity when compared to **sham stimulation or conventional therapy**.	8	Demir et al. 2018; Carda et al. 2017; Yuzer et al. 2017; Karakus et al. 2013; Hara et al. 2008; Hara et al. 2006; Ring and Rosenthal, 2005; Faghri and Rodgers, 1997
2	**FES combined with biofeedback and mirror therapy** may not have a difference in efficacy when compared to **FES combined with mirror therapy or conventional therapy** for improving spasticity.	1	Kim et al. 2015
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **cyclic NMES** for improving spasticity.	1	Boyaci et al. 2013

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **cyclic NMES** to improve range of motion when compared to **sham stimulation or conventional therapy**.	2	Tilkici et al. 2017; Malhotra et al. 2013
2	**Cyclic NMES combined with arm robotics** may not have a difference in efficacy when compared to **arm robotics on their own or conventional therapy** for improving range of motion.	1	Miyasaka et al. 2016
1b	**Cyclic NMES combined with repetitive task training** may produce greater improvements in range of motion than **repetitive task training alone**.	1	Gharib et al. 2014
2	**EMG-triggered NMES** may produce greater improvements in range of motion than **sham stimulation or conventional therapy**.	2	Heckman et al. 1997; Bowman et al. 1979
1b	**EMG-triggered NMES combined with mirror therapy** may produce greater improvements in range of motion than **mirror therapy on its own**.	1	Kojima et al. 2014
1b	There is conflicting evidence about the effect of **FES** to improve range of motion when compared to **sham stimulation or conventional therapy**.	4	Shimodozono et al. 2014; Hara et al. 2008; Hara et al. 2006; Faghri and Rodgers, 1997
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **cyclic NMES** for improving range of motion.	1	Boyaci et al. 2013
1b	**FES** may not have a difference in efficacy when compared to **cyclic NMES** for improving range of motion.	2	Knutson et al. 2016; Knutson et al. 2012

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Cyclic NMES** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving performance of activities of daily living.	3	Tilkici et al. 2017; Baygutalp et al. 2014; Lin and Yan 2011
1a	**Cyclic NMES combined with arm robotics** may not have a difference in efficacy when **compared to arm robotics on their own or conventional therapy** for improving performance of activities of daily living.	3	Barker et al. 2017; Lee et al. 2015; Hayward et al. 2013
1a	There is conflicting evidence about the effect of **EMG-triggered NMES** to improve performance of activities of daily living when compared to **sham stimulation or conventional therapy**.	5	Kwakkel et al. 2016; Dorsch et al. 2014; Kimberely et al. 2004; Cauraugh et al. 2000; Francisco et al. 1998
1a	**EMG-triggered NMES when combined with arm robotics, mirror therapy or splints** may not have a difference in efficacy when compared to these	3	Barker et al. 2017; Qian et al. 2017; Schick et al. 2017

	additional interventions on their own for improving performance of activities of daily living.		
1b	**EMG-triggered NMES combined with splints** may not have a difference in efficacy when compared **to splints on their own** for improving performance of activities of daily living.	1	Shindo et al. 2011
1a	There is conflicting evidence about the effect of **FES** to improve performance of activities of daily living when compared to **sham stimulation or conventional therapy**.	5	Demir et al. 2018; Carda et al. 2017; Marquez-Chin et al. 2017; Yuzer et al. 2017; Mangold et al. 2009
1b	**FES** may not have a difference in efficacy when compared to **mirror therapy** for improving performance of activities of daily living.	1	Mathieson et al. 2018
2	**FES combined with biofeedback and mirror therapy** may produce greater improvements in performance of activities of daily living than **FES combined with mirror therapy or conventional therapy**.	1	Kim et al. 2015
1b	**FES combined with biofeedback and mirror therapy** may not have a difference in efficacy when compared to **FES combined with mirror therapy or conventional therapy** for improving performance of activities of daily living.	1	Kim et al. 2015
1b	**Bilateral arm training combined with FES** may not have a difference in efficacy when compared to **bilateral arm training combined with sham FES** for improving performance of activities of daily living.	1	Chan et al. 2009
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **cyclic NMES** for improving performance of activities of daily living.	3	Wilson et al. 2016; Boyaci et al. 2013; Chae et al. 2009
1b	**FES** may not have a difference in efficacy when compared to **cyclic NMES** for improving performance of activities of daily living.	2	Knutson et al. 2016; Knutson et al. 2012

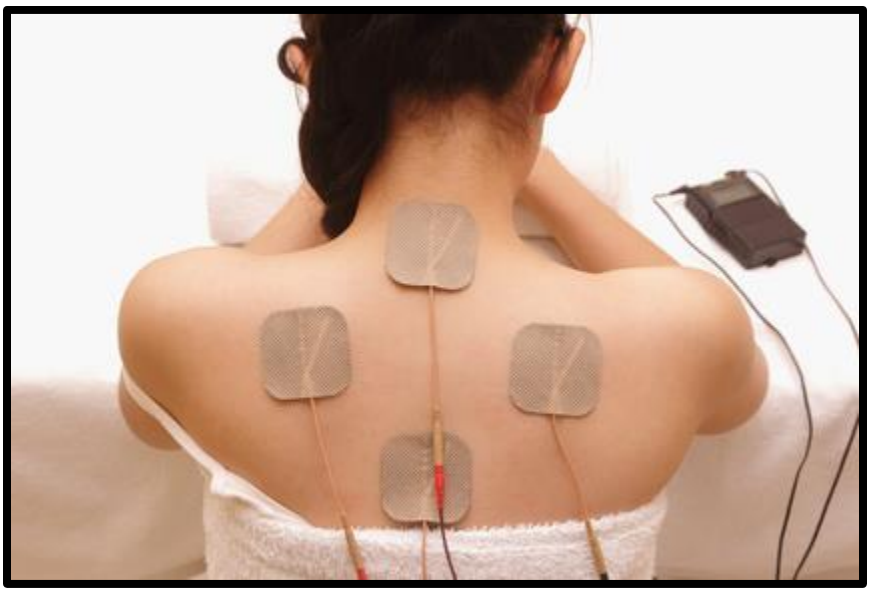
MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving muscle strength.	2	Dorsch et al. 2014; Kwakkel et al. 2016
1b	**EMG-triggered NMES combined with arm robotics** may not have a difference in efficacy when compared to **arm robotics on their own or conventional therapy** for improving muscle strength.	1	Barker et al. 2017
1b	**FES** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving muscle strength.	1	Karakus et al. 2013
2	There is conflicting evidence about the effect of **FES combined with biofeedback and mirror therapy** to improve muscle strength when compared to **FES combined with mirror therapy or conventional therapy**.	1	Kim et al. 2015
1a	**EMG-triggered NMES** may not have a difference in efficacy when compared to **cyclic NMES** for improving muscle strength.	2	Boyaci et al. 2013; De Kroon et al. 2008

Key points

The literature is mixed regrading cyclic and EMG-triggered neuromuscular electrical stimulation types, as well as functional electrical stimulation, alone or combined with other therapy approaches, for upper limb rehabilitation following stroke.

The various types of neuromuscular electrical stimulation may not be more beneficial compared to one another.

Transcutaneous electrical nerve stimulation (TENS)



Adopted from: http://www.massageprocedures.com/complementary-modalities/tens/

Transcutaneous electrical nerve stimulation (TENS) involves the application of electrical current through surface electrodes on the skin to facilitate activation of nerves (Teoli et al. 2019). Stimulation can be applied at a low frequency (<10Hz) to produce muscle contractions or at a high (>50Hz) frequency primarily used to produce paresthesia without muscle contractions (Teoli et al. 2019). TENS units are often small, portable, battery-operated devices (Teoli et al. 2019). The application of afferent electrical stimulation at the sensory level may help to enhance neuroplasticity of the brain, through increased activation and recruitment of cortical networks involving contralesional primary sensory cortex, supplementary motor area, dorsal premotor cortex, posterior parietal cortex, and secondary sensory cortices (Veldman et al. 2015; Sonde et al.1998).

A total of 15 RCTs were found that evaluated the use of TENS for upper extremity motor rehabilitation poststroke (Capone et al. 2017; Chuang et al. 2017; Jung et al. 2017; Fleming et al. 2015; dos Santos-Fontes et al. 2013; Kim et al. 2013; Ikuno et al. 2012; Klaliput et al. 2009; Celnik et al. 2007; McDonnell et al. 2007; Wu et al. 2006; Conforto et al. 2002; Sonde et al. 1998; Tekeoglu et al. 1998; Butefisch et al. 1995). Of these one RCT was a multimodal intervention combining TENS with electromyography and bilateral arm traing (Chuang et al. 2017). The rest evaluated TENS compared to sham stimulation, task specific therapy and conventional rehabilitation.

The methodological details and results of all 15 RCTs are presented in Table 23.

Table 23. RCTs evaluating TENS interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Capone et al. (2017) Quasi-RCT (8) N_{Start}=14 N_{End}=12 TPS= Chronic	E: Robot-Assisted Therapy with Transcutaneous Stimulation of Vagus Nerve (tVNS) C: Robot-Assisted Therapy with Sham-tVNS Duration: 1h, 1d/wk for 10d	• Fugl-Meyer Assessment (+exp)
Jung et al. 2017 RCT (7) N_{Start} =46 N_{End} =46 TPS= Chronic	E: Transcutaneous Electrical Nerve Stimulation and Task-Related Training C: Sham Transcutaneous Electrical Nerve Stimulation and Task-Related Training Duration: 1h, 5d/wk for 4wk	• Manual muscle test (+exp) • Active Range of Motion (+exp) • Fugl-Meyer Assessment (+exp
Fleming et al. (2015) RCT (7) N_{Start}=33 N_{End}=30 TPS=Chronic	E: Active Somatosensory Stimulation C: Sham Somatosensory Stimulation Duration: 30min/d, 3d/wk for 4wk	• Action Research Arm Test (+exp) • Fugl-Meyer Assessment (-) • Motor Activity Log (-)
dos Santos-Fontes et al. (2013) RCT (8) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Peripheral nerve stimulation C: Sham nerve stimulation Duration: 2h/d, 7d/wk for 4wk	• Jebsen Taylor Hand Function Test (+exp)
Kim et al. (2013a) RCT (7) N_{Start}=34 N_{End}=30 TPS=Chronic	E: TENS + task related training C: Placebo + Task related training Duration: 30 min, 5d/wk, for 4 wk	• Fugl-Meyer Assessment (+exp) • Manual Function Test (+exp) • Box and Block Test (+exp) • Modified Ashworth Scale (-)
Ikuno et al. (2012) RCT (8) N_{start}=22 N_{end}=22 TPS=Subacute	E: Peripheral sensory nerve stimulation + task-specific therapy C: Task-specific therapy Duration: 6d/wk for 2wk	• Wolf Motor Function Test (-) • Box and Block Test (-) • Pinch Strength (-) • Grip Strength (-)
Klaiput et al. (2009) RCT (8) N_{start}=20 N_{end}=20 TPS=Subacute	E: Peripheral nerve stimulation C: Sham stimulation Duration: 2h session	• Pinch Strength (+exp)
Celnik et al. (2007) RCT (6) N_{start}=9 N_{end}=9 TPS=Chronic	E1: Single session of peripheral nerve stimulation E2: No stimulation C: Asynchronous nerve stimulation Duration: 2h session	E1 vs E2/C • Jebsen-Taylor Hand Function Test (+exp)
McDonnell et al. (2007) RCT (7) N_{start}=20 N_{end}=20 TPS=Subacute	E: Task-specific training with TENS C: Task-specific training without TENS Duration: 1h/d, 3d/wk for 3wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Grip lift task (+exp)
Wu et al. (2006) RCT (6) N_{start}=9	E: Single session of peripheral nerve (somatosensory) stimulation	• Jebsen Taylor Hand Function Test (+exp)

N_{end}=9 TPS=Chronic	C: No stimulation Duration: 2h session	
Conforto et al. (2002) RCT (6) N_{start}=8 N_{end}=8 TPS=Chronic	E: Single session of medial nerve (somatosensory) stimulation C: Sham stimulation Duration: 2h session	• Pinch muscle strength (+exp)
Sonde et al. (1998) RCT (5) N_{start}=44 N_{end}=44 TPS=Chronic	E: TENS + physiotherapy C: Physiotherapy Duration: 60min/d, 5d/wk for 12wk	• Fugl-Meyer Assessment (+exp) • Barthel Index (-)
Tekeoglu et al. (1998) RCT (6) N_{start}=60 N_{end}=60 TPS=Subacute	E: Rehabilitation + TENS C: Rehabilitation Duration: 30min/d, 5d/wk for 8wk	• Barthel Index (+exp)
Bütefisch et al. (1995) RCT (3) N_{start}=27 N_{end}=24 TPS=Subacute	E: Enhanced specific therapy + TENS C: Enhanced non-specific therapy Duration: 15min (2x per day) for 2wk	• Grip strength (-)
EMG-triggered NMES with BAT versus EMG-TENS with BAT		
Chuang et al. (2017) RCT (7) N_{Start}=38 N_{End}=38 TPS=Chronic	E: Electromyography-Neuromuscular Electric Stimulation with Bilateral Arm Training C: Electromyography-Transcutaneous Electrical Nerve Stimulation with Bilateral Arm Training Duration: 40min, 3d/wk for 4wk	• Fugl-Meyer Assessment (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about TENS

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**TENS** may produce greater improvements in motor function than **sham stimulation, task-specific therapy or conventional therapy**.	10	Capone et al. 2017; Jung et al. 2017; Fleming et al. 2015; dos Santos-Fontes et al. 2013; Kim et al. 2013; Ikuno et al. 2012; Celnik et al. 2007; McDonnell et al. 2007; Wu et al. 2006; Sonde et al. 1998
1b	**TENS combined with EMG and bilateral training** may not have a difference in efficacy when compared to **EMG-triggered NMES and bilateral training** for improving motor function.	1	Chuang et al. 2017

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **TENS** to improve muscle strength when compared to **sham stimulation, task-specific therapy or conventional therapy**.	5	Jung et al. 2017; Ikuno et al. 2012; Klaliput et al. 2009; Conforto et al. 2002; Butefisch et al. 1995

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **TENS** to improve dexterity when compared to **sham stimulation and task-specific therapy**.	2	Kim et al. 2013; Ikuno et al. 2012

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **TENS** to improve performance of activities of daily living when compared to **sham stimulation, task-specific therapy or conventional therapy**.	3	Fleming et al. 2015; Sonde et al. 1998; Tekeoglu et al. 1998

Key points

Transcutaneous electrical nerve stimulation may be beneficial for some aspects of upper limb function following stroke.

Thermal stimulation

Adopted from: https://beautisecrets.com/paraffin-waxtreatment

Thermal stimulation is another method used to facilitate sensorimotor function, thermal stimulation applied either in a noxious or innocuous form have different effects on sensory receptors in the body (Lin et al. 2017). The perception of pain from nociceptors produced by noxious heat (>43°C) and cold (<8°C) activates brain regions such as the second somatosensory cortex, posterior insular cortex and the premotor area that would not be activated by warm and cold receptors from innocuous heat (40-43°C) and cold (20-28°C) temperatures (Lin et al. 2017). Innocuous thermal stimulation has also been found to induce greater corticomotor excitability, and as such has been suggested to influence cortical reorganization and neuroplasticity (Lin et al. 2017).

A total of 4 RCTs were found that evaluated the use of thermal stimulation for upper extremity motor rehabilitation poststroke (Lin et al. 2017; Wang et al. 2017; Wu et al. 2010; Chen et al. 2005). Noxious thermal stimulation was used in 3 RCTs with comparator groups including innocuous thermal stimulation (Lin et al. 2017), thermal stimulation on the lower extremities (Wu et al. 2010a), and conventional rehabilitation (Chen et al. 2005). Innocuous thermal stimulation through paraffin wax compared to a placebo wax was used in a single study (Wang et al. 2017).

The methodological details and results of all 4 RCTs are presented in Table 24.

Table 24. RCTs evaluating thermal stimulation interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Noxious versus innocuous thermal stimulation, lower extremity thermal stimulation and conventional rehabilitation		
Lin et al. (2017) RCT (7) N_{Start} =79 N_{End} =61 TPS= Acute	E: Noxious thermal stimulation (Heat: 46-47°C; cold: 7-8°C) C: Innocuous thermal stimulation (Heat: 40-41°C; cold: 20-21°C) Duration: 30min/d, for a total of 20-24 sessions	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Motricity Index (-) • Barthel Index (-) • Modified Ashworth Scale (-)
Wu et al. (2010a) RCT (6) N_{start}=23 N_{end}=23 TPS=Subacute	E: Thermal stimulation on upper extremity (Heat: 46-47°C; cold: 7-8°C) C: Thermal stimulation on lower extremity (Heat: 46-47°C; cold: 7-8°C)	• Stroke Rehabilitation Assessment of Movement (+exp) • Action Research Arm Test (+exp)
Chen et al. (2005) RCT (7) N_{Start}=46 N_{End}=29 TPS=Acute	E: Thermal stimulation (Heat: 46-47°C; cold: 7-8°C) C: Conventional rehabilitation	• Brunnstrom Recovery Stages (+exp) • Modified Ashworth Scale (-) • Grasping (-)
Innocuous thermal stimulation versus placebo		
Wang et al. (2017) RCT (8) N_{Start} =52 N_{End} =52 TPS= Subacute	E: Paraffin wax thermal stimulation (Heat: 40-42°C) C: Placebo paraffin thermal stimulation	• Modified Ashworth Scale (+exp) • Brunnstrom Recovery Stages (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about thermal stimulation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of N**oxious thermal stimulation** to improve motor function when compared to **innocuous thermal stimulation, thermal stimulation on the lower extremities and conventional rehabilitation.**	3	Lin et al. 2017; Wu et al. 2010; Chen et al. 2005

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Noxious thermal stimulation** may not have a difference in efficacy when compared to **innocuous thermal stimulation** for improving muscle strength.	1	Lin et al. 2017

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Noxious thermal stimulation** may not have a difference in efficacy when compared to **innocuous thermal stimulation, and conventional rehabilitation** for improving spasticity.	2	Lin et al. 2017; Chen et al. 2005
1b	**Innocuous thermal stimulation** may produce greater improvements on spasticity than **placebo**.	1	Wang et al. 2017

Key points

Noxious thermal stimulation may not be beneficial for upper limb rehabilitation following stroke, whereas innocuous thermal stimulation may improve some aspects of upper limb function.

Muscle vibration

Adopted from: https://www.humanlocomotion.org/products/focal-vibration-motors

Various forms of muscle vibration applications exist including: focal muscle vibration, whole body vibration, and stochastic resonance stimulation. Whole body vibration involves standing, sitting, or performing various tasks/movements on a vibration platform with the purpose of improving muscle strength and function (Liao et al. 2015; Park et al. 2018). Focal muscle vibration is a new therapeutic approach that involves the application of low-amplitude/high-frequency vibratory stimulation to a specific muscle through small portable devices (Celletti et al. 2017). Lastly, stochastic resonance stimulation involves the application of electrical or mechanical vibration below the sensory threshold to lower the threshold of sensation of the tactile and proprioceptive systems (Stein et al. 2010).

A total of 9 RCTs were found that evaluated the use of muscle vibration therapies for upper extremity motor rehabilitation poststroke (Calabro et al. 2017; Costantino et al. 2017; Jung-Sun et al. 2016; Paoloni et al. 2014; Tavernese et al. 2013; Caliandro et al. 2012; Stein et al. 2010).

The methodological details and results of all 9 RCTs are presented in Table 25.

Table 25. RCTs evaluating muscle vibration interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Vibration Therapy		
Calabro et al. (2017) RCT (7) N_{Start}=20 N_{End}=19 TPS=Subacute-Chronic	E: Focal Muscle Vibration C: Sham Muscle Vibration Duration: 30min/d, 5d/wk for 6wk	• Modified Ashworth Scale (+exp) • Functional Independence Measure (+exp) • Fugl-Meyer Assessment (+exp)
Costantino et al. (2017) RCT (7) N_{Start}=32 N_{End}=32 TPS=Chronic	E: 300 Hz vibrations on the upper limbs C: Sham vibrations Duration: 30min/d, 3d/wk for 4wk	• Hand Grip Strength (+exp) • Modified Ashworth Scale (+exp) • Disabilities of the Arm, Shoulder and Hand Score (+exp) • Functional Independence Measure (+exp) • Fugl-Meyer Assessment (+exp) • Jebsen Taylor Hand Function Test (+exp)
Lee et al. (2016) RCT (6) N_{Start}=45 N_{End}=45 TPS=Chronic	E1: Whole-body vibration and task-related training E2: Whole-body vibration C: Conventional Therapy Duration: 30min/d, 3d/wk for 4wk	E1/E2 vs C • Fugl-Meyer Assessment (+exp, +exp$_2$) • Grip Strength (+exp, +exp$_2$) E1 vs E2 • Grip Strength (+exp, +exp$_2$) • E1 vs E2/C • Wolf Motor Function Test (+exp) • Modified Ashworth Scale (+exp)
Paoloni et al. (2014) RCT (8) N_{Start}=22 N_{End}=22 TPS=Chronic	E: Segmental muscle vibration + conventional therapy C: Conventional therapy Duration: 30min/d, 5d/wk for 2wk	• Muscle modulation of anterior deltoid (+exp) • Muscle modulation of biceps brachii (+exp)
Tavernese et al. (2013) RCT (8) N_{Start}=44 N_{End}=44 TPS=Chronic	E: Segmental muscle vibration + standard therapy C: Standard therapy Duration: 30min/d, 5d/wk for 2wk	• Angular velocity at shoulder (+exp) • Movement duration (+exp) • Normalized jerk (+exp) • Elbow angle (-) • Shoulder angle (-) • Shoulder abduction (-)
Caliandro et al. (2012) RCT (7) N_{Start}=49 N_{End}=36 TPS=Chronic	E: Focal muscle vibration C: Sham Duration: 30min/d, for 3d	• Wolf Motor Function Test (+exp)
Stein et al. (2010) RCT (10) N_{start}=30 N_{end}=30 TPS=Chronic	E: Stochastic resonance stimulation (combination of subthreshold electrical stimulation and vibration) C: Sham stimulation Duration: 3d/wk for 4wk	• Fugl-Meyer Assessment (-) • Motor Activity Log (-) • Action Research Arm Test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about muscle vibration

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Muscle vibration therapies** may produce greater improvements in motor function than **sham vibration or conventional therapy**.	5	Calabro et al. 2017; Costantino et al. 2017; Lee et al. 2016; Caliandro et al. 2012; Stein et al. 2010

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Muscle vibration therapies** may produce greater improvements in muscle strength than **sham vibration or conventional therapy**.	3	Costantino et al. 2017; Lee et al. 2016; Paoloni et al. 2014

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **muscle vibration therapies** to improve performance of activities of daily living when compared to **sham vibration or conventional therapy**.	3	Calabro et al. 2017; Costantino et al. 2017; Stein et al. 2010

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Muscle vibration therapies** may produce greater improvements in spasticity than **sham vibration or conventional therapy**.	2	Calabro et al. 2017; Lee et al. 2016

Key points

Muscle vibration may be beneficial for improving upper limb function following stroke.

Additional afferent and peripheral stimulation methods

Adopted from: https://www.saebo.com/saebostim-micro/

Additional sensory stimulation methods evaluated for motor rehabilitation included short wave therapy, repetitive peripheral magnetic stimulation, and intermittent pneumatic compression. Short-wave therapy is a non-invasive intervention in which electromagnetic radiation is applied to the region of the body typically at 27.12MHz in a continuous or pulse fashion (Wang et al. 2017). In repetitive peripheral magnetic stimulation coils are placed over paralysed muscles that generates a magnetic field that passes through the skin, and in turn can depolarize neurons to allow a muscle contraction (Momosaki et al. 2017). Repetitive peripheral magnetic stimulation can stimulate painlessly deep muscle structures that are out of range of traditional electrical stimulation (Momosaki et al. 2017). Intermittent pneumatic compression is the application of inflatable splints where pressure is applied intermittently to increase sensory input (Cambier et al. 2003).

Additionally, a few studies looked at the effects of mirror therapy combined with the Mesh Glove, a novel form of technology that can apply sensory stimulation of varying intensities throughout the hand (Lee et al. 2015; Lin et al. 2014a; Lin et al. 2014b).

A total of 9 RCTs were found that evaluated the use of afferent and peripheral stimulation for upper extremity motor rehabilitation poststroke (Kattenstroth et al. 2018; Lee et al. 2015; Krewer et al. 2014; Lin et al. 2014a; Lin et al. 2014b; Hunter et al. 2011; Cambier et al. 2003; Feys et al. 1998; Jongbloed et al. 1989).

The methodological details and results of all 9 RCTs are presented in Table 26.

Table 26. RCTs evaluating afferent and peripheral stimulation interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Additional methods for Sensory/Afferent Stimulation		
Kattenstroth et al. (2018) RCT (4) N_{Start} =71 N_{End} =48 TPS= Acute	E: Repetitive Sensory Stimulation C: Sham Repetitive Sensory Stimulation Duration: 45min/d, 5d/wk for 2wk	• Tactile Discrimination (+exp) • Grating Orientation Task (+exp) • Grip Strength (+exp) • 9 Hole Peg Test (-) • Jebsen Taylor Hand Function Test (-) • Joint Position Sense Test (-)
Krewer et al. (2014) RCT (9) N_{Start}=63 N_{End}=44 TPS=Chronic	E: Repetitive peripheral magnetic stimulation C: Sham stimulation Duration: 20min/d, 2d/wk for 2wk	• Modified Tardieu Scale (-) • Fugl-Meyer Assessment (-) • Barthel Index (-)
Hunter et al. (2011) RCT (7) N_{start}=76 N_{end}=75 TPS= Acute	E: Mobilization and Tactile Stimulation (3 dose levels) C: Conventional therapy Duration: 30-120min (3x per day), 5d/wk for 2wk	• Motricity Index (-) • Action Research Arm Test (-)
Cambier et al. (2003) RCT (7) N_{start}=23 N_{end}=23 TPS=Subacute	E: Intermittent pneumatic compression C: Sham short-wave therapy Duration: 30min/d, 5d/wk for 4wk	• Nottingham Sensory Assessment (+exp) • Fugl-Meyer Assessment (+exp) • Ashworth Scale (-)
Feys et al. (1998) RCT (6) N_{start}=100 N_{end}=100 TPS=Acute	E: Short-wave therapy stimulation with splints C: Sham stimulation Duration: 30min/d, 5d/wk for 6wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Barthel Index (-)
Jongbloed et al. (1989) RCT (5) N_{start}=90 N_{end}=87 TPS=Subacute	E: Sensorimotor integrative approach C: Functional approach Duration: *Not reported*	• Barthel Index (-) • Sensorimotor Integration Test (-)
Mirror therapy with Mesh sensory stimulation gloves versus mirror therapy		
Lee et al. (2015) RCT (7) N_{Start}=48 N_{End}=47 TPS=Chronic	E1: Mirror Therapy with Mesh Glove Afferent Stimulation E2: Mirror Therapy C: Mirror Therapy with Sham Stimulation Duration: 90min/d, 5d/wk for 4wk	E1 vs E2/C • Extensor Digitorum Muscle Tone (+exp) E1/C vs E2 • Box and Block Test: (+exp, +con) • Muscle stiffness on the flexor carpi radialis (+exp, +con) • Functional Independence Measure (+exp, +con) • Fugl-Meyer Assessment (-) • Revised Nottingham Sensory Assessment (-)
Lin et al. (2014a) RCT (7) N_{Start}=16 N_{End}=16 TPS=Chronic	E: Mirror therapy + Mesh glove C: Mirror therapy Duration: 90min/d, 5d/wk for 4wk	• Modified Ashworth Scale (-) • Box and Block Test (+exp) • Functional Independence Measure (-) • Action Research Arm Test (+exp)
Lin et al. (2014b) RCT (7)	E1: Mirror therapy + Mesh glove E2: Mirror therapy C: Therapeutic exercises	E1 vs C • Fugl-Meyer Assessment (+exp) E1 vs E2 & E1 vs C

N_{Start}=43 N_{End}=42 TPS=Chronic	Duration: 90min/d, 5d/wk for 4wk	• Box and Block Test (+exp) E1 vs E2 • Wolf Motor Function Test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about additional afferent and peripheral stimulation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Sensory stimulation methods such as short-wave therapy, repetitive magnetic stimulation and intermittent pneumatic compression** may not have a difference in efficacy when compared to **sham stimulation, conventional therapy and functional approaches** for improving motor function.	6	Kattenstroth et al. 2018; Krewer et al. 2014; Hunter et al. 2011; McDonnell et al. 2007; Cambier et al. 2003; Feys et al. 1998
1a	There is conflicting evidence about the effect of **mirror therapy combined with Mesh Gloves** to improve motor function when compared to **mirror therapy on its own**.	3	Lee et al. 2015; Lin et al. 2014a; Lin et al. 2014b

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **sensory stimulation methods such as repetitive sensory stimulation and tactile stimulation** to improve muscle strength when compared to **sham stimulation and conventional therapy**.	2	Kattenstroth et al. 2018; Hunter et al. 2011

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **sensory stimulation methods such as short-wave therapy, repetitive magnetic stimulation and intermittent pneumatic compression** to improve dexterity when compared to **sham stimulation, conventional therapy and functional approaches**.	2	Kattenstroth et al. 2018; McDonell et al. 2007
1a	**Mirror therapy combined with Mesh Gloves** may produce greater improvements in dexterity than **mirror therapy on its own**.	3	Lee et al. 2015; Lin et al. 2014a; Lin et al. 2014b

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Sensory stimulation methods such as short-wave therapy, repetitive magnetic stimulation and intermittent pneumatic compression** may not have a difference in efficacy when compared to **sham stimulation, conventional therapy and functional approaches** for improving performance of activities of daily living.	3	Krewer et al. 2014; Feys et al. 1998; Jongbloed et al. 1989
1a	There is conflicting evidence about the effect of **mirror therapy combined with Mesh Gloves** to improve	2	Lee et al. 2015; Lin et al. 2014a

	performance of activities of daily living when compared to **mirror therapy on its own**.		

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Sensory stimulation methods such as short-wave therapy, repetitive magnetic stimulation and intermittent pneumatic compression** may not have a difference in efficacy when compared to **sham stimulation, conventional therapy and functional approaches** for improving spasticity.	3	Krewer et al. 2014; Cambier et al. 2003; Jongbloed et al. 1989
1b	**Mirror therapy when combined with Mesh Gloves** may not have a difference in efficacy when compared to **mirror therapy on its own** for improving spasticity.	1	Lin et al. 2014a

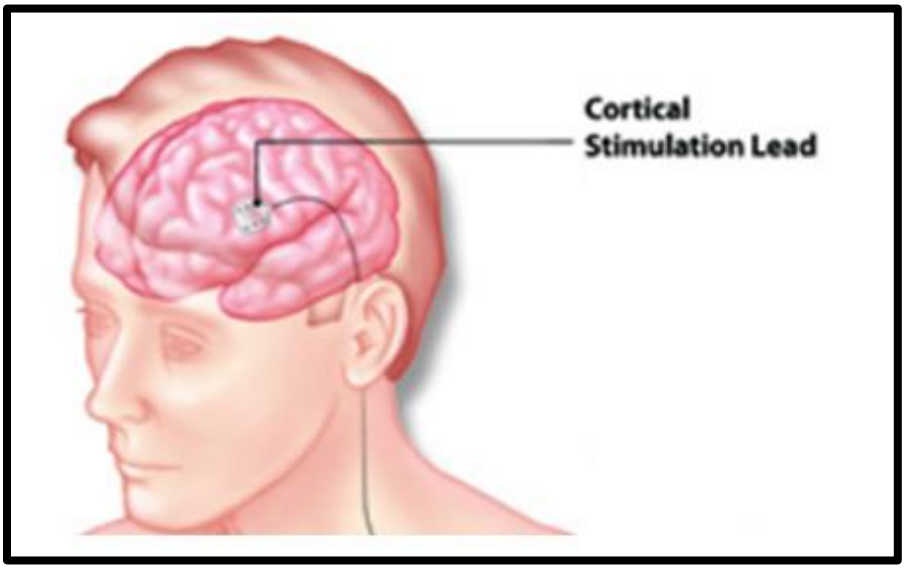
PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **sensory stimulation methods such as short-wave therapy, repetitive magnetic stimulation and intermittent pneumatic compression** to improve proprioception when compared to **sham stimulation, conventional therapy and functional approaches**.	2	Kattenstroth et al. 2018; Cambier et al. 2003

Key points

The literature is mixed regarding additional afferent and peripheral stimulation for upper limb rehabilitation following stroke.

Invasive central nervous system stimulation

Invasive cortical and nerve electrode implant stimulation



Adopted from: https://www.medgadget.com/2008/01/brain_stimulation_device_for_stroke_victims_fails_clinical_trial.html

Cortical stimulation in the motor cortex was traditionally used for the management of neuropathic pain, but preclinical evidence from animal models and clinical observations of pain patients showing motor improvements using this technique led to its adoption as an intervention for motor rehabilitation in stroke survivors (Levy et al. 2008; Tsubokawa et al. 1991). The neurosurgical procedure is performed through an extradural craniotomy where the stimulation electrode is placed on the dura matter of the motor cortex in a region predetermined from stereotaxic neuronavigation and functional magnetic resonance imaging (Levy et al. 2016; Brown et al. 2006). The frequency of stimulation is typically at 50Hz, and stimulation parameters remain consistent for the length of the intervention (Levy et al. 2016; Huang et al. 2008).

However, due to the invasive nature of this procedure and potential for adverse events, RCTs mainly investigating this technique for stroke rehabiltiation were feasibility studies (Brown et al. 2006; Huang et al. 2008; Levy et al. 2008), and only recently a phase III clinical trial (Levy et al. 2016).

Vagus nerve stimulation has been shown in preclinical evidence from animal models to influence neuroplasticity, as stimulation can lead to increased acetylcholine and norepinephrine release, both of which are involved in the reorganization of cortical networks (Dawson et al. 2016). As well as pairing upper limb rehabilitation with vagus nerve stimulation has been shown to further promote plasticity in preclinical settings (Hays et al. 2016). Only one study has looked at vagus nerve stimulation with upper limb rehabilitation in stroke survivors (Dawson et al. 2016).

The methodological details and results of 5 RCTs (Levy et al. 2016; Dawson et al. 2016; Huang et al. 2008; Levy et al. 2008; Brown et al. 2006) that have evaluated the use of invasive cortical and nerve stimulation methods for improving motor function post stroke are presented in Table 27.

Table 27. RCTs evaluating invasive brain stimulation interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Motor cortex stimulation		
Levy et al. (2016) RCT (6) N_{Start}=164 N_{End}=128 TPS=Chronic	E: Cortical implant with epidural 6-contact lead perpendicular to the primary motor cortex and a pulse generator C: Conventional rehabilitation Duration: *Not Specified*	• Arm Motor Ability Test (-) • Fugl-Meyer Assessment (-)
Huang et al. (2008) RCT (5) N_{start}=24 N_{end}=24 TPS=Chronic	E1: Motor cortex stimulation (50Hz) C1: Conventional rehabilitation E2: Motor cortex stimulation (101Hz) C2: Conventional rehabilitation Duration: 2.5hr/d, 5d/wk for 4 wk	• Fugl Meyer Score (+exp, +exp$_2$) • Box and Block Test (+exp, +exp$_2$) • Stroke Impact Scale (-) • Arm Motor Ability Test (-) • Grip strength (-)
Levy et al. (2008) RCT (5) N_{start}=24 N_{end}=24 TPS=Chronic	E: Motor cortex stimulation C: Conventional rehabilitation Duration: *Not Specified*	• Fugl Meyer Score (+exp) • Arm Motor Ability Test (+exp)
Brown et al. (2006) RCT (6) N_{start}=10 N_{end}=10 TPS=Chronic	E: Motor cortex stimulation C: Conventional rehabilitation Duration: 30min/d, 5d/wk for 3 wk	• Fugl Meyer Scale (+exp) • Stroke Impact Scale (+exp)
Vagus nerve stimulation		
Dawson et al. (2016) RCT (7) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Impanted vagus nerve stimulation C: Conventional rehabilitation Duration: 20min/d, 4 d/wk for 8 wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (-) • Grip Strength (-) • Nine Hole Peg Test (-) • Box and Block Test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about invasive cortical and nerve stimulation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **motor cortex stimulation** to improve motor function when compared to **conventional therapy**.	4	Levy et al. 2016; Huang et al. 2008; Levy et al. 2008; Brown et al. 2006
1b	There is conflicting evidence about the effect of **vagus nerve stimulation** to improve motor function when compared to **conventional therapy**.	1	Dawson et al. 2016

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Motor cortex stimulation** may not have a difference in efficacy when compared to **conventional therapy** for improving muscle strength.	1	Huang et al. 2008
1b	**Vagus nerve stimulation** may not have a difference in efficacy when compared to **conventional therapy** for improving muscle strength.	1	Dawson et al. 2016

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Motor cortex stimulation** may produce greater improvements in dexterity than **conventional therapy**.	1	Huang et al. 2008
1b	**Vagus nerve stimulation** may not have a difference in efficacy when compared to **conventional therapy** for improving dexterity.	1	Dawson et al. 2016

ACTIVITIES OF DAILY LIVING			
1a	There is conflicting evidence about the effect of **motor cortex stimulation** to improve performance of activities of daily living when compared to **conventional therapy**.	3	Levy et al. 2016; Huang et al. 2008; Brown et al. 2006

Key points

The literature is mixed regarding invasive cortical and nerve stimulation for upper limb rehabilitation following stroke.

Non-invasive brain stimulation

Repetitive Transcranial Magnetic Stimulation (rTMS)

Adopted from: https://www.rtmscentre.co.uk/rtms-treatment-in-the-uk/

Transcranial magnetic stimulation is a painless and non-invasive method of affecting neural activity through the exogenous generation of an electromagnetic field through a coil placed on the scalp, that consequently induces a change in the electrical fields of the brain (Peterchev et al. 2012). The voltage and current of the electromagnetic field generated are dependent on the parameters of the stimulation device, which is not distorted by the biological tissues in which it is applied in (Peterchev et al. 2012). The neuromodulatory effects of transcranial magnetic stimulation are attributed largely to neural membrane polarization shifts that can lead to changes in neuron activity, synaptic transmission, and activation of neural networks (Peterchev et al. 2012). Repetitive transcranial magnetic stimulation (rTMS) is the application of repetitive trains of transcranial magnetic stimulation at regular intervals.

After a stroke, interhemispheric competition is altered; with cortical excitability increasing in the unaffected hemisphere increasing and decreasing in the affected hemisphere (Zhang et al. 2017). rTMS can be used to help modulate this interhemispheric competition, with low stimulation frequencies (≤1Hz) decreasing cortical excitability and inhibiting activity of the contralesional hemisphere, while high frequency (>1Hz) stimulation increases excitability and have a facilitatory effect on activity of the ipsilesional hemisphere (Dionisio et al. 2018).

A growing number of studies have investigated the effects of rTMS on improving upper extremity motor rehabilitation after a stroke. Low frequency rTMS versus sham stimulation or conventional therapy was assessed in 28 RCTs (Long et al. 2018; Tarri et al. 2018; Watanabe et al. 2018; Askin et al. 2017; Meng and Song, 2017; Ozkeskin et al. 2017; Yang et al. 2017; Du et al. 2016; Li et al. 2016; Cassidy et al. 2015; Ludermann-Podubecka et al. 2015; Abo et al. 2014; Barros Galvao et al. 2014; Rose et al. 2014; Wang et al. 2014; Etoh et al. 2013; Higgins et al. 2013; Saskai et al. 2013; Conforto et al. 2012; Seniow et al. 2012; Emara et al. 2010; Khedr et al. 2009; Takeuchi et al. 2008; Liepert et al. 2007; Pomeroy et al. 2007; Fregni et al. 2006; Mansur et al. 2005; Takeuchi et al. 2005), while high frequency rTMS versus sham stimulation or conventional therapy was assessed in 13 RCTs (Guan et al. 2017; Du et al. 2016;

Hosomi et al. 2016; Li et al. 2016; Cassidy et al. 2015; Kim et al. 2014; Saskai et al. 2013; Chang et al. 2010; Emara et al. 2010; Khedr et al. 2010; Khedr et al. 2009; Malcom et al. 2007; Khedr et al. 2005). RCTs looking at multimodal interventions with rTMS were limited, and combinations included bilateral stimulation (both high and low frequency rTMS; (Long et al. 2018; Takeuchi et al. 2009)), mirror therapy (Ji et al. 2014), virtual reality (Zheng et al. 2015), sensory cueing (Yang et al. 2017) and cyclic NMES (Tosun et al. 2017). The methodological details and results of all 39 RCTs evaluating rTMS for the upper extremity motor rehabilitation are presented in Table 28.

Table 28. RCTs evaluating rTMS interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Low frequency (1Hz) rTMS vs sham stimulation or conventional therapy		
Long et al. 2018 RCT (7) N_{Start} =62 N_{End} =62 TPS=Acute	E1: Low Frequency (1Hz) combined with High Frequency (10Hz) Repetitive Transcranial Magnetic Stimulation E2: Low Frequency (1Hz) Repetitive Transcranial Magnetic Stimulation C: Sham Repetitive Transcranial Magnetic Stimulation Duration: *Not specified*	E2 vs C • Fugl-Meyer Assessment (+exp$_2$) • Wolf Motor Function Test (-)
Tarri et al. 2018 RCT (6) N_{Start} =24 N_{End} =24 TPS=Subacute	E: Paired associative stimulation (electrical stimulation + low frequency (1Hz) rTMS) C: Sham Stimulation Duration: *Not specified*	• Fugl-Meyer Assessment (-)
Watanabe et al. (2018) RCT (5) N_{Start} =21 N_{End} =21 TPS=Acute	E1: Intermittent Theta-Burst Stimulation E2: Low Frequency (1Hz) Repetitive Transcranial Magnetic Stimulation C: Sham Stimulation Duration: *Not specified*	E2 vs C • Fugl-Meyer Assessment: (-) • Stroke Impairment Assessment Set (-) • Modified Ashworth Scale (+exp$_2$) • Grip Strength (-)
Askin et al. 2017 RCT (7) N_{Start} =40 N_{End} =40 TPS=Chronic	E: Low frequency (1Hz) Repetitive Transcranial Magnetic Stimulation to unaffected hemisphere C: Conventional Physical Therapy Duration: 1 hr/d, 5d/wk, for 2wk	• Box and Block Test (+exp) • Functional Independence Measure (+exp) • Brunnstrom Recovery Stages (-) • Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-)
Meng & Song 2017 RCT (6) N_{Start} =20 N_{End} =20 TPS=NR	E: Low Frequency (1Hz) Repetitive Transcranial Magnetic Stimulation to unaffected hemisphere C: Sham Repetitive Transcranial Magnetic Stimulation Duration: 30 min/d, 7d/wk for 2wk	• National Institute of Health Stroke Scale (+exp) • Barthel Index (+exp) • Fugl-Meyer Assessment (+exp)
Ozkeskin et al. 2017 RCT (9) N_{Start} =21 N_{End} =21 TPS=Chronic	E: Low frequency (1Hz) Repetitive Transcranial Magnetic Stimulation to unaffected hemisphere C: Sham Repetitive Transcranial Magnetic Stimulation Duration: 90 min/d, 5d/wk for 2wk	• Brunnstrom Recovery Stages (-) • Finger Touch Localization (-) • Modified Ashworth Scale (-) • Wrist Proprioceptive Evaluations (+exp)
Du et al. (2016) RCT (7) N_{Start} =69 N_{End} =59 TPS=Acute	E1: High frequency (3Hz) rTMS E2: Low frequency (1Hz) rTMS C: Sham rTMS Duration: 30min/d, 5d/wk for 1wk	E2 vs C • Fugl-Meyer Assessment (+exp$_2$) • Medical Research Council Score (+exp$_2$) • National Institute of Health Stroke Scale (+exp$_2$) • Modified Rankin Scale (+exp$_2$) • Barthel Index (+exp$_2$)
Li et al. (2016) RCT (7) N_{Start} =127 N_{End} =127 TPS=Subacute	E1: Low frequency (1Hz) rTMS E2: High frequency (10Hz) rTMS C: Sham Duration: 40min/d, 5d/wk for 2wk	E1 vs C • Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (-)

Ludemann-Podubecka et al. (2016) RCT (7) N_{Start} =10 N_{End} =10 TPS=Subacute	E: Low frequency (1Hz) rTMS C: Sham Duration: 30min/d, 5d/wk for 6wk	• Jebsen Taylor Hand Function Test (+exp) • Box and Block Test (-)
Cassidy et al. (2015) RCT (7) N_{Start} =11 N_{End} =11 TPS=Chronic	E1: High frequency (6Hz) rTMS E2: Low frequency (1Hz) rTMS C: Sham Duration: 1hr/d, 3d/wk for 5wk	E2 vs. C • Box and Block Test ($+exp_2$)
Ludemann-Podubecka et al. (2015) RCT (7) N_{Start} =40 N_{End} =33 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: 30min/d, 5d/wk for 6 wk	• Wolf Motor Function Test (+exp) • Motor Evaluation Scale (+exp) • Finger Tapping (-)
Abo et al. (2014) RCT (7) N_{Start}=66 N_{End}=66 TPS=Chronic	E: Low frequency (1Hz) rTMS + OT training (NEURO) C: CIMT Duration: 20min rTMS & 120min OT (2x/d), 6d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp)
Barros Galvao et al. (2014) RCT (8) N_{Start}=20 N_{End}=18 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: 1hr/d, 5d/wk for 2wk	• Modified Ashworth Scale (-) • Fugl-Meyer Assessment (-) • Functional Independence Measure (-) • Wrist range of motion (-)
Rose et al. (2014) RCT (5) N_{Start}=22 N_{End}=19 TPS=Chronic	E: Low frequency (1Hz) rTMS + functional task practice (FTP) C: Sham + FTP Duration: 1.5hr/d, 4d/wk, 4wk	• Wolf Motor Function Test (-) • Pinch strength (lateral and palmar) (-) • Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Modified Ashworth Scale (-) • Motor Activity Log (-)
Wang et al. (2014) RCT (9) N_{Start}=44 N_{End}=44 TPS=Chronic	E1: Low frequency (1Hz) rTMS applied to primary motor cortex E2: Low frequency (1Hz) rTMS applied to premotor area C: Sham Duration: *Not Specified*	E1 vs C • Wolf Motor Function Test (+exp) • Fugl-Meyer Assessment (+exp) • Medical Research Council Scale (+exp) E2 vs C • Wolf Motor Function Test: ($+exp_2$) • Fugl-Meyer Assessment: ($+exp_2$) • Medical Research Council Scale ($+exp_2$) E1 vs E2 • Wolf Motor Function Test (+exp) • Fugl-Meyer Assessment (+exp) • Medical Research Council Scale (+exp)
Etoh et al. 2013 RCT Crossover (7) N_{Start}=18 N_{End}=18 TPS=Chronic	E1: Low frequency (1Hz) rTMS C: Sham rTMS Duration: 4min, 5d/wk for 2wk	• Action Research Arm Test (+exp) • Fugl Meyer Assessment (-) • Simple test for evaluating hand function (-) • Modified Ashworth scale (-)
Higgins et al. (2013) RCT (7) N_{Start}=11 N_{End}=11 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: 90min/d, 4d/wk for 4wk	• Box and Block Test (-) • Motor Acitivity Log (-) • Wolf Motor Function Test (-)
Sasaki et al. (2013) RCT (8)	E1: High frequency (10Hz) rTMS E2: 1Hz rTMS non-lesioned hemisphere	E2 vs C • Grip strength (-)

N_{Start}=29 N_{End}=29 TPS=Acute	C: Sham Duration: 45min/d, 2d/wk for 6wk	• Tapping frequency (-)
Conforto et al. (2012) RCT (6) N_{start}=29 N_{end}=28 TPS=Acute	E: Low frequency (1Hz) rTMS C: Sham Duration: 25min/d, 5d/wk for 4wk	• Jebsen-Taylor Hand Function test (+exp) • Pinch Force (+exp) • Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (-)
Seniów et al. (2012) RCT (8) N_{start}=40 N_{end}=33 TPS=Chronic	E: Low frequency (1Hz) rTMS + PT C: Sham + PT Duration: 75min/d, 5d/wk for 3wk	• Wolf Motor Function Test (-) • Fugl-Meyer Assessment (-)
Emara et al. (2010) RCT (7) N_{start}=60 N_{end}=60 TPS=Subacute	E1: High frequency (5Hz) rTMS E2: Low frequency (1Hz) rTMS C: Sham Duration: 30min/d, 5d/wk for 4wk	E2 vs C • Finger tapping test (+exp_2) • Frenchay Activities Index (+exp_2) • Modified Rankin Scale (+exp_2)
Khedr et al. (2009) RCT (8) N_{start}=36 N_{end}=36 TPS=Acute	E1: Low frequency (1Hz) rTMS E2: High frequency (3Hz) rTMS C: Sham Duration: 30min/d, 3d/wk for 4wk	E1 vs C • Grip strength (+exp) • Purdue Pegboard task (+exp) • Barthel Index (+exp) • NIHSS (+exp)
Takeuchi et al. (2008) RCT (7) N_{start}=20 N_{end}=20 TPS=Chronic	E: Low frequency (1Hz) rTMS + pinch force motor training C: Sham + pinch force motor training Duration: *Not Specified*	• Pinch force (+exp)
Liepert et al. (2007) RCT (7) N_{start}=12 N_{end}=12 TPS=Acute	E: Low frequency (1Hz) rTMS C: Sham Duration: 3hr/d, 3d/wk for 4wk	• Grip strength (-) • 9-hole peg test (+exp)
Pomeroy et al. (2007) RCT (8) N_{start}=27 N_{end}=24 TPS=Chronic	E1: Low frequency (0.5Hz) rTMS + voluntary muscle contraction (VMC) E2: Low frequency (0.5Hz) rTMS + placebo VMC E3: Sham rTMS + VMC C: Sham rTMS + placebo VMC Duration: *Not Specified*	• Flexion/extension torque (-) • Action Research Arm Test (-)
Fregni et al. (2006) RCT (7) N_{start}=15 N_{end}=15 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: 20min/d, 5d/wk for 6wk	• Jebsen-Taylor Hand Function test (+exp)
Mansur et al. (2005) RCT (4) N_{start}=10 N_{end}=10 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: *Not Specified*	• Finger tapping test (-) • Perdue Pegboard test (+exp)
Takeuchi et al. (2005) RCT (6) N_{start}=20 N_{end}=20 TPS=Chronic	E: Low frequency (1Hz) rTMS C: Sham Duration: 25min/d, 3d/wk for 5wk	• Hand and pinch force (-)
High frequency (>1Hz) rTMS vs Sham or conventional therapy		
Guan et al. 2017 RCT (5) N_{Start} =42 N_{End} =27 TPS=Acute	E: High frequency (5Hz) Repetitive Transcranial Magnetic Stimulation C: Sham Repetitive Transcranial Magnetic Stimulation Duration: 25 min/d, 4d/wk for 6wk	• National Institutes of Health Stroke Scale (+exp) • Barthel Index (+exp) • Fugl-Meyer Assessment (+exp) • Modified Rankin Score (-)

Du et al. (2016) RCT (7) N_{Start} =69 N_{End} =55 TPS=Acute	E1: High frequency (3Hz) rTMS E2: Low frequency (1Hz) rTMS C: Sham rTMS Duration: 30min/d, 5d/wk for 1wk	E1 vs C • Fugl-Meyer Assessment (-) • Medical Research Council Score (-) • National Institute of Health Stroke Scale (+exp) • Modified Rankin Scale (+exp) • Barthel Index (+exp)
Hosomi et al. (2016) RCT (8) N_{Start} =41 N_{End} =39 TPS=Subacute	E: High frequency (5Hz) rTMS C: Sham Duration: 1hr/d, 5d/wk for 2wk	• Brunnstorm Recovery Stages (-) • Fugl-Meyer Assessment (-) • National institute for Health Stroke Scale (-) • Grip Power (-)
Li et al. (2016) RCT (7) N_{Start} =127 N_{End} =127 TPS=Subacute	E1: Low frequency (1Hz) rTMS E2: High frequency (10Hz) rTMS C: Sham Duration: 40min/d, 5d/wk for 2wk	E2 vs C • Fugl-Meyer Assessment (+exp_2) • Wolf Motor Function Test (-)
Kim (2014) RCT (6) N_{Start}=31 N_{End}=31 TPS=Chronic	E: High frequency (10Hz) rTMS C: Sham Duration: 10min/d, 5d/wk for 4wk	• Manual Function Test (+exp)
Sasaki et al. (2013) RCT (8) N_{Start}=29 N_{End}=29 TPS=Acute	E1: 10Hz rTMS lesioned hemisphere E2: 1Hz rTMS non-lesioned hemisphere C: Sham Duration: 45min/d, 2d/wk for 6wk	E1 vs C • Grip strength (+exp) • Tapping frequency (+exp)
Chang et al. (2010) RCT (5) N_{start}=28 N_{end}=28 TPS=Subacute	E: High frequency (10Hz) rTMS C: Sham Duration: 2min, 5d/wk for 2wk	• Motricity Index (+exp) • Fugl-Meyer Assessment (-)
Emara et al. (2010) RCT (7) N_{start}=60 N_{end}=60 TPS=Subacute	E1: 5Hz rTMS E2: 1Hz rTMS C: Sham Duration: 30min/d, 5d/wk for 4wk	E1 vs C • Finger tapping test (+exp) • Frenchay Activities Index (+exp) • Modified Rankin Scale (+exp)
Khedr et al. (2010) RCT (8) N_{start}=48 N_{end}=38 TPS=Acute	E1: 3Hz rTMS E2: 10Hz rTMS C: Sham Duration: 30min/d, 3d/wk for 4wk	E1/E2 vs C • Grip strength (+exp, +exp_2) • NIHSS (+exp, +exp_2) • Modified Rankin Scale (+exp, +exp_2) E1 vs E2 • Grip strength (-) • NIHSS (-) Modified Rankin Scale (-)
Khedr et al. (2009) RCT (8) N_{start}=36 N_{end}=36 TPS=Acute	E1: 1Hz rTMS E2: 3Hz rTMS C: Sham Duration: 30min/d, 3d/wk for 4wk	E2 vs C • Grip strength (+exp_2) • Purdue Pegboard task (+exp_2) • Barthel Index (+exp_2) • NIHSS (+exp_2)
Malcolm et al. (2007) RCT (6) N_{start}=19 N_{end}=19 TPS=Chronic	E: High frequency (20Hz) rTMS C: Sham Duration: 40min/d, 6d/wk for 5wk	• Wolf Motor Function Test (-) • Motor Activity Log (-)
Khedr et al. (2005) RCT (6) N_{start}=52 N_{end}=52	E: High frequency (3Hz) rTMS C: Sham Duration: 45min/d, 5d/wk, 2wk	• Barthel Index (+exp) • NIHSS (+exp) • Scandinavian Stroke Impact Scale (+exp)

TPS=Acute		
Low frequency combined with high frequency rTMS or low frequency versus high frequency rTMS		
Long et al. 2018 RCT (7) N_{Start} =62 N_{End} =62 TPS=Acute	E1: Low Frequency Combined with High Frequency Repetitive Transcranial Magnetic Stimulation E2: Low Frequency Repetitive Transcranial Magnetic Stimulation C: Sham Repetitive Transcranial Magnetic Stimulation Duration: *Not Specified*	E1 vs C • Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) E1 vs E2 • Fugl-Meyer Assessment (-) • Wolf Motor Function Test (+exp)
Takeuchi et al. (2009) RCT (6) N_{start}=30 N_{end}=30 TPS=Chronic	E1: Bilateral (dual) rTMS (1Hz and 10Hz) E2: 10Hz rTMS E3: 1Hz rTMS Duration: 15min/d, 3d/wk for 5wk	E1 vs E2 • Pinch force (+exp) E1 vs E3 • Pinch force (+exp)
rTMS plus an additional intervention		
Tosun et al. 2017 RCT (7) N_{Start} =25 N_{End} =25 TPS=Subacute	E1: Low Frequency (1Hz) Repetitive Transcranial Magnetic Stimulation E2: Low Frequency Repetitive Transcranial with Cyclic NMES C: Physical Therapy Duration: 1 hr/d, 5d/wk for 4wk	E1/E2 vs C; E1 vs E2 • Fugl-Meyer Assessment (-) • Motricity Index (-) • Brunnstrom Recovery Stages (-) • Modified Ashworth Scale (-) • Barthel Index (-)
Yang et al. (2017) RCT (8) N_{Start} =60 N_{End} =60 TPS=Subacute	E1: Low frequency (1Hz) Repetitive Transcranial Magnetic Stimulation with Sensory Cueing E2: Low frequency (1Hz) Repetitive Transcranial Magnetic Stimulation C: Conventional Therapy Duration: 45 min/d, 5d/wk for 4wk	E1 vs C • Fugl-Meyer Assessment (-) • Action Research Arm Test (-) Modified Barthel Index (-) E2 vs C • Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Modified Barthel Index (-) E1 vs E2 • Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Modified Barthel Index (-)
Zheng et al. (2015) RCT (7) N_{Start}=112 N_{End}=108 TPS=Chronic	E: Low frequency (1Hz) rTMS + virtual reality (VR) training C: Sham + VR training Duration: 45min/d, 6d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp) • Modified Barthel Index (+exp)
Ji et al. (2014) RCT (7) N_{Start}=35 N_{End}=35 TPS=Chronic	E1: Mirror therapy + high frequency (10Hz) rTMS E2: Mirror therapy C: Sham Duration: 15 min/d, 6d/wk for 4wk	E1 vs E2 • Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp) E1 vs C • Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about rTMS

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **low frequency rTMS** to improve motor function when compared to **sham stimulation or conventional therapy**.	20	Long et al. 2018; Tarri et al. 2018; Watanabe et al. 2018; Askin et al. 2017; Meng and Song, 2017; Ozkesin et al. 2017; Yang et al. 2017; Du et al. 2016; Li et al. 2016; Ludermann-Podubecka et al. 2015; Abo et al. 2014; Barros Galvao et al. 2014; Rose et al. 2014; Wang et al. 2014; Etoh et al. 2013; Higgins et al. 2013; Conforto et al. 2012; Seniow et al. 2012; Pomeroy et al. 2007; Fregni et al. 2006
1a	**High frequency rTMS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving motor function.	7	Guan et al. 2017; Du et al. 2016; Hosomi et al. 2016; Li et al. 2016; Kim et al. 2014; Chang et al. 2010; Malcom et al. 2007
1b	There is conflicting evidence about the effect of **bilateral rTMS stimulation (both high and low frequency)** to improve motor function when compared to **sham stimulation or conventional therapy**.	1	Long et al. 2018
1b	**Low frequency rTMS with sensory cueing** may not have a difference in efficacy when compared to **low frequency rTMS or sham stimulation** for improving motor function.	1	Yang et al. 2017
1b	**Low frequency rTMS combined with virtual reality training** may produce greater improvements in motor function than **virtual reality training on its own or sham stimulation combined with virtual reality**.	1	Zheng et al. 2015
1b	**Mirror therapy combined with high frequency rTMS** may produce greater improvements in motor function than **mirror therapy on its own or sham stimulation**.	1	Ji et al. 2014
1b	**Low frequency rTMS with cyclic NMES** may not have a difference in efficacy when compared to **low frequency rTMS or conventional therapy** for improving motor function.	1	Tosun et al. 2017

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **low frequency rTMS** to improve dexterity when compared to **sham stimulation or conventional therapy**.	10	Askin et al. 2017; Ozkeskin et al. 2017; Cassidy et al. 2015; Ludermann-Podubecka et al. 2015; Higgins et al. 2013; Saskai et al. 2013; Emara et al. 2010; Khedr et al. 2009; Liepert et al. 2007; Mansur et al. 2005
1a	**High frequency rTMS** may produce greater improvements in dexterity than **sham stimulation or conventional therapy**.	4	Cassidy et al. 2015; Saskai et al. 2013; Emara et al. 2010; Khedr et al. 2009
1b	**Mirror therapy combined with high frequency rTMS** may produce greater improvements in dexterity	1	Ji et al. 2014

	than **mirror therapy on its own or sham stimulation**.		

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Low frequency rTMS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving spasticity.	7	Watanabe et al. 2018; Askin et al. 2017; Ozkeskin et al. 2017; Barros Galvao et al. 2014; Rose et al. 2014; Etoh et al. 2013; Conforto et al. 2012
1b	**Low frequency rTMS with cyclic NMES** may not have a difference in efficacy when compared to **low frequency rTMS or conventional therapy** for improving spasticity.	1	Tosun et al. 2017

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Low frequency rTMS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving range of motion.	2	Barros Galvao et al. 2014; Pomeroy et al. 2007

PROPRIOCEPTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Low frequency rTMS** may produce greater improvements in proprioception than **sham stimulation or conventional therapy**.	1	Ozkeskin et al. 2017

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Low frequency rTMS** may produce greater improvements on measures of stroke severity than **sham stimulation or conventional therapy**.	5	Askin et al. 2017; Meng and Song, 2017; Du et al. 2016; Emara et al. 2010; Khedr et al. 2009
1a	**High frequency rTMS** may produce greater improvements on measures of stroke severity than **sham stimulation or conventional therapy**.	6	Guan et al. 2017; Du et al. 2016; Hosomi et al. 2016; Emara et al. 2010; Khedr et al. 2010; Khedr et al. 2009
1b	**Low frequency rTMS with cyclic NMES** may not have a difference in efficacy when compared to **low frequency rTMS or conventional therapy** for improvements on measures of stroke severity.	1	Tosun et al. 2017

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **low frequency rTMS** to improve performance of activities of daily living when compared to **sham stimulation or conventional therapy**.	9	Askin et al. 2017; Meng and Song, 2017; Yang et al. 2017; Du et al. 2016; Barros Galvao et al. 2014; Rose et al. 2014; Higgins et al. 2013; Emara et al. 2010; Khedr et al. 2009
1a	**High frequency rTMS** may produce greater improvements in performance of activities of daily living than **sham stimulation or conventional therapy**.	6	Guan et al. 2017; Du et al. 2016; Emara et al. 2010; Khedr et al. 2009; Malcom et al. 2007; Khedr et al. 2005
1b	**Low frequency rTMS with sensory cueing** may not have a difference in efficacy when compared to **low frequency rTMS or sham stimulation** for improving performance of activities of daily living.	1	Yang et al. 2017
1b	**Low frequency rTMS combined with virtual reality training** may produce greater improvements in performance of activities of daily living than **virtual reality training on its own or sham stimulation combined with virtual reality**.	1	Zheng et al. 2015
1b	**Low frequency rTMS with cyclic NMES** may not have a difference in efficacy when compared to **low frequency rTMS or conventional therapy** for improving performance of activities of daily living.	1	Tosun et al. 2017

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **low frequency rTMS** to improve muscle strength when compared to **sham stimulation or conventional therapy**.	10	Watanabe et al. 2018; Du et al. 2016; Rose et al. 2014; Wang et al. 2014; Saskai et al. 2013; Conforto et al. 2012; Khedr et al. 2009; Takeuchi et al. 2008; Liepert et al. 2007; Takeuchi et al. 2005
1a	**High frequency rTMS** may produce greater improvements in muscle strength than **sham stimulation or conventional therapy**.	6	Du et al. 2016; Hosomi et al. 2016; Saskai et al. 2013; Chang et al. 2010; Khedr et al. 2010; Khedr et al. 2009
1a	**Bilateral rTMS stimulation (both high and low frequency)** may produce greater improvements in muscle strength than **low frequency rTMS**.	1	Takeuchi et al. 2009
1a	**Bilateral rTMS stimulation (both high and low frequency)** may produce greater improvements in muscle strength than **high frequency rTMS**.	1	Takeuchi et al. 2009
1b	**Low frequency rTMS with cyclic NMES** may not have a difference in efficacy when compared to **low frequency rTMS or conventional therapy** for improving muscle strength.	1	Tosun et al. 2017

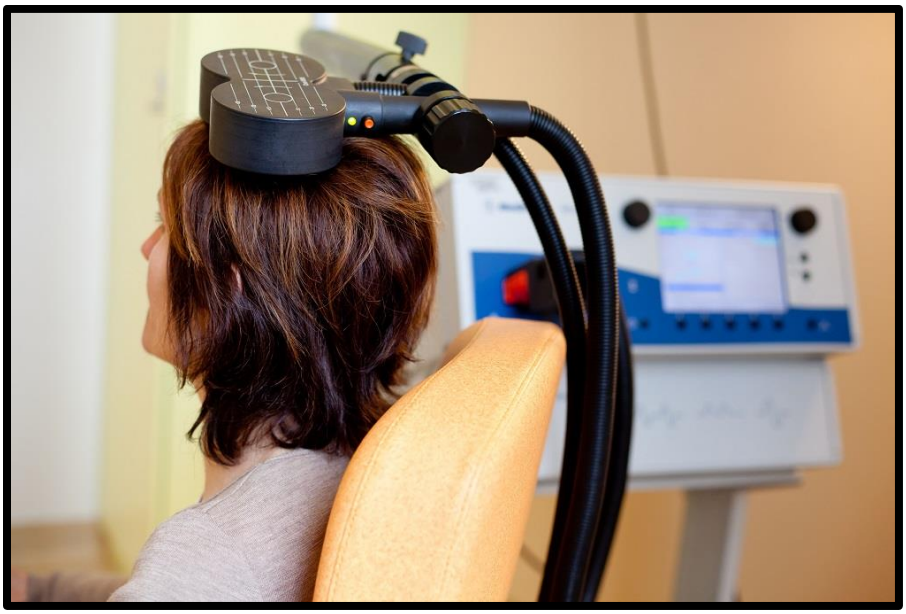
Key points

The literature is mixed regarding low frequency repetitive transcranial magnetic stimulation, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

High frequency repetitive transcranial magnetic stimulation, alone or in combination with other therapy approaches, may be beneficial for upper limb rehabilitation.

The literature is mixed regarding bilateral repetitive transcranial magnetic stimulation for upper limb rehabilitation.

Theta burst stimulation (TBS)



Adopted from: https://www.psychiatryadvisor.com/home/depression-advisor/intermittent-theta-burst-stimulation-for-major-depressive-disorder-treatment/

Theta Burst Stimulation (TBS) is an emerging treatment modality that is a patterned form of rTMS where stimulation pulses are delivered in triplets or bursts at a high frequency (50Hz), and in a short interval (200ms), intending to mimic naturally occurring theta brain oscillations (Schwippel et al. 2019). TBS can also be used to adjust interhemispheric rivalry after a stroke and promote motor recovery through the delivery of continuous TBS (cTBS) to reduce cortical excitability in the contralesional hemisphere (600 pulses over 40 seconds); or intermittent TBS (iTBS) to increase cortical excitability in the ipsilesional hemisphere (600 pulses over 190 seconds) (Schwippel et al. 2019; Cotoi et al. 2019).

A total of 9 RCTs were found that evaluated the use of TBS for upper extremity motor rehabilitation poststroke (Watanabe et al. 2018; Ackerley et al. 2016; Di Lazzaro et al. 2016; Volz et al. 2016; Kim et al. 2015; Di Lazzaro et al. 2014; Hsu et al. 2013; Sung et al. 2013; Talelli et al. 2012). Six RCTs evaluated the effects of iTBS (Watanabe et al. 2018; Ackerley et al. 2016; Volz et al. 2016; Kim et al. 2015; Hsu et al. 2013; Talelli et al. 2012), and three RCTs the effects of cTBS (Di Lazzaro et al. 2016; Di Lazzaro et al. 2014; Talelli et al. 2012), both compared to sham TBS for improving upper extremity motor rehabilitation outcomes. Additionally, one RCT evaluated the effects of iTBS combined with low frequency rTMS compared to sham TBS/rTMS for improving upper extremity motor rehabilitation outcomes.

The methodological details and results of all 10 RCTs are presented in Table 29.

Table 29. RCTs evaluating TBS interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Intermittent TBS versus sham stimulation		
Watanabe et al. (2018) RCT (5) N_{Start} =21 N_{End} =21 TPS=Acute	E1: Intermittent Theta-Burst Stimulation E2: Low Frequency Repetitive Transcranial Magnetic Stimulation C: Sham Stimulation Duration: *Not Specified*	E1 vs C: • Fugl-Meyer Assessment (-) • Stroke Impairment Assessment Set (-) • Modified Ashworth Scale (-) • Grip Strength (-)
Ackerley et al. (2016) RCT (8) N_{Start}=18 N_{End}=18 TPS=Chronic	E: iTBS C: Sham TBS Duration: 45min/d, 5d/wk for 2wk	• Action Research Arm Test (+exp) • Fugl-Meyer Assessment (-)
Volz et al. (2016) RCT (5) N_{Start}=26 N_{End}=17 TPS=Acute	E: iTBS C: Sham TBS Duration: *Not Specified*	• Grip Strength (+exp) • Jebsen Taylor Hand Function Test (-)
Kim et al. (2015) RCT (8) N_{Start}=15 N_{End}=15 TPS=Chronic	E: iTBS C: Sham TBS Duration: 30min/d, 3d/wk for 4wk	• Modified Tardieu Scale (+exp) • Peak torque (+exp) • Modified Ashworth Scale (+exp)
Hsu et al. (2013) RCT (7) N_{start}=12 N_{end}=12 TPS=Subacute	E: iTBS C: Sham Duration: 30min/d, 3d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (-)
Talelli et al. (2012) RCT (7) N_{start}=41 N_{end}=41 TPS=Chronic	E: iTBS C: Sham iTBS Duration: 1hr/d, 5d/wk for 2wk	• Nine Hole Peg Test (-) • Jebsen Taylor Hand test (-)
Intermittent TBS + low frequency rTMS versus sham TBS and/or sham rTMS		
Sung et al. (2013) RCT (6) N_{Start}=54 N_{End}=54 TPS= Chronic	E1: Low frequency (1Hz) rTMS + iTBS E2: Sham rTMS + iTBS E3: Low frequency (1Hz) rTMS + sham iTBS C: Sham rTMS + sham ltbs Duration: 45min/d, 5d/wk for 4wk	E1/E2/E3 vs C • Wolf Motor Function test (+exp, +exp$_2$, +exp$_3$) • Fugl-Meyer Assessment (+exp, +exp$_2$, +exp$_3$) • Medical Research Council Scale (+exp, +exp$_2$, +exp$_3$) • Functional Independence Measure (-) E1 vs E2 • Wolf Motor Function test (+exp) • Fugl-Meyer Assessment (+exp) • Medical Research Council Scale (+exp) • Functional Independence Measure (-) E1 vs E3 • Wolf Motor Function test (+exp) • Fugl-Meyer Assessment (-) • Medical Research Council Scale (+exp)

		• Functional Independence Measure (-) E2 vs E3 • Wolf Motor Function test (-) • Fugl-Meyer Assessment (+exp$_3$) • Medical Research Council Scale (+exp$_3$) • Functional Independence Measure (-)
Continuous TBS versus sham stimulation		
Di Lazzaro et al. (2016) RCT (7) N_{Start}=20 N_{End}=17 TPS=Chronic	E: cTBS + robotic therapy C: Sham TBS + robotic therapy Duration: 1hr/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-)
Di Lazzaro et al. (2014) RCT (6) N_{Start}=12 N_{End}=12 TPS=Chronic	E: cTBS C: Sham Duration: 40min/d, 5d/wk for 2wk	• Action Research Arm Test (-) • Nine Hole Peg Test (-) • Jebsen Taylor hand test (-) • Grasp strength (-) • Pinch strength (-)
Talelli et al. (2012) RCT (7) N_{start}=41 N_{end}=41 TPS=Chronic	E: cTBS C: Sham cTBS Duration: 1hr/d, 5d/wk for 2wk	• Nine Hole Peg Test (-) • Jebsen Taylor Hand test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about TBS

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**iTBS** may not have a difference in efficacy when compared to **sham stimulation** for improving motor function.	6	Watanabe et al. 2018; Ackerley et al. 2016; Volz et al. 2016; Kim et al. 2015; Hsu et al. 2013; Talelli et al. 2012
1a	**cTBS** may not have a difference in efficacy when compared to **sham stimulation** for improving motor function.	3	Di Larazzo et al. 2016; Di Larazzo et al. 2014; Talelli et al. 2012
1b	**iTBS combined with low frequency rTMS** may produce greater improvements in motor function than **sham stimulation with or without iTBS**.	1	Sung et al. 2013
1b	There is conflicting evidence about the effect of **iTBS combined with low frequency rTMS** to improve motor function when compared to **sham stimulation with low frequency rTMS**.	1	Sung et al. 2013

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**iTBS** may produce greater improvements in muscle strength than **sham stimulation**.	4	Watanabe et al. 2018; Volz et al. 2016; Kim et al. 2015; Sung et al. 2013
1b	**cTBS** may not have a difference in efficacy when compared to **sham stimulation** for improving muscle strength.	1	Di Larazzo et al. 2014
1b	**iTBS combined with low frequency rTMS** may produce greater improvements in muscle strength than **sham stimulation with or without iTBS**.	1	Sung et al. 2013

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**iTBS** may not have a difference in efficacy when compared to **sham stimulation** for dexterity.	1	Talelli et al. 2012
1a	**cTBS** may not have a difference in efficacy when compared to **sham stimulation** for dexterity.	2	Di Lazzero et al. 2014; Talelli et al. 2012

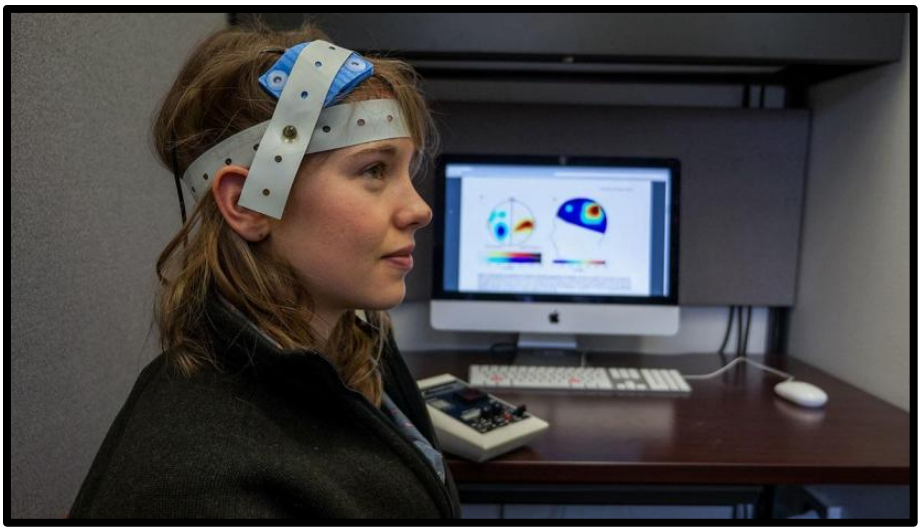
ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**iTBS** may not have a difference in efficacy when compared to **sham stimulation** for improving performance of activities of daily living.	2	Watanabe et al. 2018; Sung et al. 2013
1b	**iTBS combined with low frequency rTMS** may not have a difference in efficacy when compared to **sham stimulation or low frequency rTMS and iTBS on their own** for improving performance of activities of daily living.	1	Sung et al. 2013

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b, 2	There is conflicting evidence about the effect of **iTBS** to improve spasticity when compared to **sham stimulation**.	2	Watanabe et al. 2018; Kim et al. 2015

Key points

Theta burst stimulation alone may not be beneficial for upper limb function following stroke, however it may be beneficial for certain aspects of upper limb function when used in combination with repetitive transcranial magnetic stimulation.

Transcranial Direct Current Stimulation (tDCS)



Adopted from: https://tryniakaufman.com/2018/01/11/transcranial-direct-current-stimulation-the-drug-of-the-future/

Another form of non-invasive brain stimulation is transcranial direct-current stimulation (tDCS). This procedure involves the application of mild electrical currents (1-2 mA) conducted through two saline-soaked, surface electrodes applied to the scalp, overlaying the area of interest and the contralateral forehead above the orbit. Anodal stimulation is performed over the affected hemisphere and increases cortical excitability, while cathodal stimulation is performed over the unaffected hemisphere and decreases cortical excitability (Alonso-Alonso et al., 2007). Additionally, tDCS can be applied on both hemispheres concurrently, this is known as dual tDCS. In contrast to TMS, tDCS does not induce action potentials, but instead modulates the resting membrane potential of the neurons (Alonso-Alonso et al., 2007).

45 RCTs were found that evaluated tDCS interventions for upper extremity motor rehabilitation (Dehem et al. 2018; Shaheiwola et al. 2018; Andrade et al. 2017; Del Felice et al. 2017; Hong et al. 2017; Koh et al. 2017; Marquez et al. 2017; Mazzoleni et al. 2017; Pavlova et al. 2017; Rabadi et al. 2017; Takebayshi et al. 2017; Allman et al. 2016; Figlewski et al. 2016; Goodwill et al. 2016; Ilic et al. 2016; Mortensen et al. 2016; Powell et al. 2016; Rocha et al. 2016; Straudi et al. 2016; Ang et al. 2015; Cunningham et al. 2015; Lee et al. 2015; Sattler et al. 2015; Sik et al. 2015; Triccas et al. 2015; Au Yeung et al. 2014; Cha et al. 2014; Fusco et al. 2014; Hendy et al. 2014; Lee et al. 2014; Lefebvre et al. 2014; Viana et al. 2014; Fusco et al. 2013; Khedr et al. 2013; Lefebvre et al. 2013; Wu et al. 2013; Stagg et al. 2012; Zimmerman et al. 2012; Hesse et al. 2011; Tanaka et al. 2011; Kim et al. 2010; Lindenberg et al. 2010; Kim et al. 2009; Boggio et al. 2007; Fregni et al. 2005).

17 RCTs compared anodal tDCS to sham stimulation (Andrade et al. 2017; Marquez et al. 2017; Pavlova et al. 2017; Allman et al. 2016; Ilic et al. 2016; Mortensen et al. 2016; Sik et al. 2015; Au Yeung et al. 2014; Fusco et al. 2013; Khedr et al. 2013; Stagg et al. 2012; Hesse et al. 2011; Tanaka et al. 2011; Kim et al. 2010; Kim et al. 2009; Boggio et al. 2007; Fregni et al. 2005).

14 RCTs compared cathodal tDCS to sham stimulation or conventional therapy (Marquez et al. 2017; Rabadi et al. 2017; Lee et al. 2015; Au Yeung et al. 2014; Fusco et al. 2014; Fusco et al.

2013; Khedr et al. 2013; Wu et al. 2013; Stagg et al. 2012; Zimmerman et al. 2012; Hesse et al. 2011; Kim et al. 2010; Boggio et al. 2007; Fregni et al. 2005).

Eight RCTs compared dual tDCS to sham stimulation or conventional therapy (Koh et al. 2017; Goodwill et al. 2016; Sik et al. 2015; Cha et al. 2014; Lefebvre et al. 2014; Fusco et al. 2013; Lefebvre et al. 2013; Lindenberg et al. 2010).

Five RCTs compared anodal tDCS versus cathodal tDCS (Khedr et al. 2013; Stagg et al. 2012; Hesse et al. 2011; Boggio et al. 2007; Fregni et al. 2005). One RCT compared cathodal tDCS to dual tDCS (Del Felice et al. 2017). One RCT combined anodal tDCS with strength training (Hendy et al. 2014). Three RCTs compared anodal or cathodal tDCS with CIMT to sham stimulation with CIMT (Figlewski et al. 2016; Rocha et al. 2016; Cunningham et al. 2015). One RCT combined dual tDCS with cyclic NMES and CIMT (Takebayshi et al. 2017).

Four RCTs compared dual or anodal tDCS with robotics compared to sham stimulation with robotics or robotics alone (Dehem et al. 2018; Mazzoleni et al. 2017; Straudi et al. 2016; Triccas et al. 2015). One RCT compared anodal tDCS with robotics to cathodal tDCS with robotics (Ochi et al. 2013). Two RCTs compared anodal or dual tDCS with brain computer interfaces to sham stimulation with brain computer interfaces (Hong et al. 2017; Ang et al. 2015). One RCT compared dual tDCS with functional electrical stimulation to sham tDCS with functional electrical stimulation (Shaheiwola et al. 2018). Two RCTs compared anodal tDCS with or without peripheral nerve stimulation to peripheral nerve stimulation (Powell et al. 2016; Sattler et al. 2015). One RCT compared dual tDCS with low frequency rTMS and mirror therapy to sham tDCS and mirror therapy.

Two RCTs compared anodal or cathodal tDCS with virtual reality to virtual reality interventions with or without sham stimulation (Lee et al. 2014; Viana et al. 2014).

The methodological details and results of all 45 RCTs are presented in Table 30.

Table 30. RCTs evaluating tDCS interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Anodal tDCS versus sham stimulation		
Andrade et al. (2017) RCT (9) N_{Start} =60 N_{End} =60 TPS=Subacute	E1: Anodal Transcranial Direct Current Stimulation in Ipsilesional M1 and Constraint Induced Movement Therapy E2: Anodal Transcranial Direct Current Stimulation in Ipsilesional PMC and Constraint Induced Movement Therapy C: Sham Stimulation and Constraint Induced Movement Therapy Duration: 30min/d, 5d/wk for 6wk	E2 vs E1/C • Fugl-Meyer Assessment (+exp$_2$) • Modified Ashworth Scale (+exp$_2$) • Box and Block Test (+exp$_2$) • Medical Research Council (+exp$_2$) • Barthel Index (+exp$_2$)
Pavlova et al. 2017 RCT (7) N_{Start} =11 N_{End} =11 TPS=Chronic	E: Anodal tDCS C: Sham tDCS Duration: 20min (2x/d), 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-) • Box and Block Test (-)
Allman et al. (2016) RCT (7) N_{Start}=26 N_{End}=24 TPS=Chronic	E: Anodal tDCS C: Sham tDCS Duration: 1hr/d, for 9d	• Action Research Arm Test (+exp) • Wolf Motor Function Test (+exp) • Fugl-Meyer Assessment (-)
Ilic et al. (2016) RCT (8) N_{Start}=26 N_{End}=25 TPS=Chronic	E: Anodal tDCS + occupational therapy C: Sham tDCS + occupational therapy Duration: 45min/d, 5d/wk for 2wk	• Jebsen-Taylor Hand Function Test (+exp) • Fugl-Meyer Assessment (-) • Grip Strength (-)
Mortensen et al. (2016) RCT (7) N_{Start}=16 N_{End}=15 TPS=Chronic	E: Anodal tDCS + occupational therapy C: Sham tDCS + occupational therapy Duration: 30min/d for 5d	• Grip Strength (+exp) • Stroke Impact Scale (-) • Jebsen-Taylor Hand Function Test (-)
Tanaka et al. (2011) RCT (6) N_{start}=8 N_{end}=8 TPS=Subacute	E: Anodal tDCS C: Sham Duration: 30min/d, 4d/wk for 5wk	• Grip strength (-)
Kim et al. (2009) RCT (7) N_{start}=10 N_{end}=10 TPS=Subacute	E: Anodal tDCS C: Sham Duration: 20min/d, 5d/wk for 6wk	• Box & Block Test (+exp) • Finger acceleration (+exp)
Cathodal tDCS versus sham stimulation or conventional therapy		
Rabadi et al. 2017 RCT (7) N_{Start} =16 N_{End} =12 TPS=Acute	E: Cathodal tDCS C: Sham tDCS Duration: 30min/d, 5d/wk for 2wk	• Action Research Arm Test (-)
Lee et al. (2015) RCT (6) N_{Start}=24 N_{End}=24 TPS=Chronic	E: Cathodal tDCS + physical therapy C: Physical therapy Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp)
Fusco et al. (2014) RCT (6)	E: Cathodal tDCS + active electrode C: Sham tDCS	• Canadian Neurologic Scale (-) • Nine Hole Peg Test (-)

N_{Start}=14 N_{End}=11 TPS=Subacute	Duration: 45min/d, 5d/wk for 2wk	• Barthel Index (-) • Fugl-Meyer Assessment (-)
Wu et al.(2013) RCT (9) N_{Start}=90 N_{End}=90 TPS=Chronic	E: Cathodal tDCS C: Sham tDCS Duration: 20min/d, 5d/wk for 4wk	• Modified Ashworth Scale (+exp)
Zimerman et al. (2012) RCT (6) N_{start}=12 N_{end}=12 TPS=Chronic	E: Cathodal tDCS C: Sham tDCS Duration: *Not Specified*	• Grip strength (-)
Hummel et al. (2005) RCT (6) N_{start}=6 N_{end}=6 TPS=Chronic	E: Cathodal tDCS C: Sham tDCS Duration: 20min/d, 3d/wk for 4wk	• Jebsen-Taylor Hand Function test (+exp)
Dual tDCS versus sham stimulation or conventional therapy		
Koh et al. (2017) RCT (8) N_{Start} =25 N_{End} =18 TPS=Chronic	E: Dual tDCS with Sensory Modulation C: Sham tDCS with Sensory Modulation Duration: 30min/d, 5d/wk for 8wk	• Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-) • Action Research Arm Test (-) • Barthel Index (-)
Goodwill et al. (2016) RCT (7) N_{Start} =16 N_{End} =15 TPS=Chronic	E: Dual tDCS + upper limb training C: Sham tDCS + upper limb training Duration: 30min/d, 5d/wk for 3wk	• Tardieu Scale (-) • Grip Strength (-)
Lefebvre et al. (2015) RCT Crossover (5) N_{Start} =19 N_{End} =19 TPS=Chronic	E: Dual tDCS C: Sham tDCS Duration: 30min/d, 5d/wk for 3wk	• Purdue Pegboard Test (+exp)
Cha et al. (2014) RCT (6) N_{Start}=20 N_{End}=20 TPS=Chronic	E: Dual tDCS C: Conventional training Duration: 30min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Box and Block Test (+exp)
Lefebvre et al. (2014) RCT (8) N_{Start}=19 N_{End}=19 TPS=Chronic	E: Dual tDCS C: Sham Duration: 20min/d, 5d/wk for 2wk	• Purdue Pegboard Test (+exp) • Precision grip (+exp)
Lefebvre et al. (2013) RCT (8) N_{Start}=18 N_{End}=18 TPS=Chronic	E: Dual tDCS C: Sham Duration: 30min/d, 4d/wk for 3wk	• Purdue Pegboard Test (+exp) • Maximal hand grip force (+exp)
Lindenberg et al. (2010) RCT (4) N_{start}=20 N_{end}=20 TPS=Chronic	E: Dual tDCS C: Sham Duration: 30min/d, 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test (+exp)
Anodal or cathodal tDCS versus sham stimulation		
Marquez et al. 2017 RCT Crossover (8) N_{Start} =25 N_{End} =25 TPS=Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham tDCS Duration: 20min/d for 6d	E1/E2 vs C • Jebsen-Taylor Hand Function test (-) • Grip Strength (-)

Au-Yeung et al. (2014) RCT Crossover (8) N_{Start}=10 N_{End}=10 TPS=Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: *Not Specified*	E1/E2 vs C • Purdue Pegboard Test (-) • Pinch strength (-)
Khedr et al.(2013) RCT (9) N_{Start}=40 N_{End}=40 TPS= Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: 25min/d for 6d	E1/E2 vs C • Orgogozo MCA scale (+exp, +exp$_2$) • National Institute of Health Stroke Scale (-) • Barthel Index (+exp, +exp$_2$) • Medical Research Council Scale (-) E1 vs E2 • Orgogozo MCA scale (-) • National Institute of Health Stroke Scale (-) • Barthel Index (-) • Medical Research Council Scale (-)
Stagg et al. (2012) RCT (6) N_{start}=13 N_{end}=13 TPS=Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: 80min/d, 3d/wk for 4wk	E1/E2 vs C • Grip strength (+exp, +exp$_2$) E1 vs E2 • Grip strength (-)
Hesse et al. (2011) RCT (10) N_{start}=96 N_{end}=85 TPS=Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: 20min/d, 5d/wk for 6wk	E1/E2 vs C • Fugl-Meyer Assessment (-) E1 vs E2 • Fugl-Meyer Assessment (-)
Kim et al. (2010) RCT (7) N_{start}=18 N_{end}=16 TPS=Subacute	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: Not Specified	E2 vs C • Fugl-Meyer Assessment (+exp$_2$) • Barthel Index (-) E1 vs C • Fugl-Meyer Assessment (-) • Barthel Index (-)
Boggio et al. (2007) RCT (6) N_{start}=4 N_{end}=4 TPS=Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: 20min, 1x/wk for 4wk	E1/E2 vs C • Jebsen-Taylor Hand Function test (+exp, +exp$_2$) E1 vs E2 • Jebsen-Taylor Hand Function test (-)
Fregni et al. (2005) RCT (7) N_{start}=6 N_{end}=6 TPS= Chronic	E1: Anodal tDCS E2: Cathodal tDCS C: Sham Duration: *Not Specified*	E1/E2 vs C • Jebsen Taylor Hand Function test: (+exp, +exp$_2$) E1 vs E2 • Jebsen Taylor Hand Function test: (-)
Anodal, cathodal or dual tDCS versus sham stimulation		
Sik et al. (2015) RCT (6) N_{start}=36 N_{end}=31 TPS=Subacute	E1: Anodal tDCS + PT + OT E2: Dual tDCS + PT + OT C: Sham tDCS + PT + OT Duration: *Not Specified*	E1/E2 vs C • Wolf Motor Function Test (+exp, +exp$_2$) • Jebsen Taylor Hand Function Test (+exp, +exp$_2$) • Kocaeli Functional Evaluation Test (+exp$_2$) E1 vs E2 • Wolf Motor Function Test (-), • Jebsen Taylor Hand Function Test (-) • Kocaeli Functional Evaluation Test (-)
Fusco et al. (2013) RCT (7) N_{start}=9 N_{end}=9 TPS=Subacute	E1: Dual tDCS E2: Anodal tDCS E3: Cathodal tDCS C: Sham Duration: 15min/d for 2d	E1/E2/E3 vs C • Nine hole peg test (+exp, +exp$_2$, +exp$_3$) • Grasp force (-)
Cathodal versus dual tDCS stimulation		

Del Felice et al. 2017 RCT crossover (8) N_{Start} =10 N_{End} =10 TPS=Chronic	E: Cathodal Trans Direct Current Stimulation C: Dual tDCS Duration: 20min/d, 5d/wk for 3wk	• Modified Ashworth Scale (+exp) • Bhakta Finger Flexion Scale (-) • European Stroke Scale (-) • Action Research Arm Test (-) • Medical Research Council Scale (-) • Barthel Index (-)
Anodal tDCS with strength training compared to sham tDCS with strength training		
Hendy et al. (2014) RCT (7) N_{Start}=10 N_{End}=10 TPS=Chronic	E1: Strength training + anodal tDCS E2: Strength training + sham C: Anodal tDCS Duration: 20min/d, 2d/wk for 5wk	• Maximum voluntary dynamic strength for wrist extensors (-)
Anodal or cathodal tDCS with CIMT		
Figlewski et al. (2016) RCT (7) N_{Start}=44 N_{End}=44 TPS=Chronic	E: CIMT + Anodal tDCS C: CIMT + Sham tDCS Duration: 6hr/d for 9d	• Wolf Motor Function Test (+exp) • Grip Strength (-) • Arm Strength (-)
Rocha et al. (2016) RCT (8) N_{Start}=21 N_{End}=21 TPS=Chronic	E1: Anodal tDCS with CIMT E2: Cathodal tDCS with CIMT C: Sham tDCS with CIMT Duration: 1hr/d, 6d/wk for 2wk	E1 vs C • Fugl-Meyer Assessment (+exp) • Motor Acivity Log (-) • Grip Strength (-) E2 vs C • Fugl-Meyer Assessment (-) • Motor Acivity Log (-) • Grip Strength (-)
Cunningham et al. (2015) RCT (6) N_{Start}=12 N_{End}=12 TPS=Chronic	E: anodal tDCS + CIMT C: Sham tDCS + CIMT Duration: 30min/d, 3d/wk for 10wk	• 9 Hole Peg Test (-) • Motor Activity Log (-) • Fugl-Meyer Assessment (-)
Dual tDCS with cyclic NMES and CIMT		
Takebayshi et al. 2017 RCT (7) N_{Start} =20 N_{End} =19 TPS=Chronic	E: Dual tDCS combined with cyclic NMES with CIMT C: CIMT Duration: 2hr (2x/d), 5d/wk for 3wk	• Fugl-Meyer Assessment (+exp) • Motor Activity Log (+exp)
Dual or anodal tDCS with robotics compared to sham tDCS with robotics or robotics alone		
Dehem et al. (2018) RCT-crossover (6) N_{Start} =21 N_{End} =20 TPS=Chronic	E: Dual tDCS with Upper Limb Robotic Assisted Therapy C: Sham tDCS with Upper Limb Robotic Assisted Therapy Duration: 45min/d, 5d/wk for 6wk	• Box and Block Test (+exp) • Purdue Pegboard Test (-)
Straudi et al. (2016) RCT (6) N_{Start} =23 N_{End} =23 TPS=Subacute and chronic	E: Robot-assisted therapy + dual tDCS C: Robot-assisted therapy + sham tDCS Duration: 45min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-) • Box and Block Test (-) • Motor Acivity Log (-)
Mazzoleni et al. 2017 RCT (7) N_{Start} =24 N_{End} =24 TPS=Acute	E: Anodal tDCS with Wrist Robot-Assisted Training C: Wrist Robot-Assisted Training Duration: *Not Specified*	• Fugl-Meyer Assessment (-) • Modified Ashworth Scale (-) • Motricity Index (-) • Box and Block Test (-)
Triccas et al. (2015) RCT (8) N_{start}=23 N_{end}=22 TPS=Subacute	E: Anodal tDCS + robotic ArmeoSpring C: Sham tDCS + robotic ArmeoSpring Duration: 45min/d, 3d/wk for 4wk	• Fugl-Meyer Assessment (-) • Action Research Arm Test (-) • Motor Activity Log (-) • Stroke Impact Scale (-)

Anodal versus cathodal tDCS stimulation with robotics		
Ochi et al. (2013) RCT (7) N_{start}=18 N_{end}=16 TPS=Chronic	E: Anodal tDCS on affected hemisphere + robot assisted arm training C: Cathodal tDCS on unaffected hemisphere + robot assisted arm training Duration: 45min/d, for 5d	• Modified Ashworth Scale (+exp) • Fugl-Meyer Assessment (-) • Motor Activity Log (-)
Anodal or dual tDCS with brain computer interface-assisted motor imagery		
Hong et al. (2017) RCT (5) N_{Start} =19 N_{End} =19 TPS=Chronic	E: Brain computer interface -Assisted Motor Imagery with Dual tDCS C: Brain computer interface -Assisted Motor Imagery with Sham tDCS Duration: 20min/d, 5d/wk for 2wk	• Fugl-Meyer Assessment (-)
Ang et al. (2015) RCT (6) N_{Start} =19 N_{End} =19 TPS=Chronic	E: Anodal tDCS + motor imagery brain computer interface with robotic feedback C: Sham tDCS + motor imagery brain computer interface with robotic feedback Duration: 80min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-)
Dual tDCS with FES		
Shaheiwola et al. 2018 RCT (6) N_{Start} =30 N_{End} =30 TPS=Chronic	E: Dual tDCS with FES C: Sham tDCS with FES Duration: 45min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Wolf Motor Function Test Score (+exp) • Modified Ashworth Scale (-)
Anodal tDCS with peripheral nerve stimulation		
Powell et al. (2016) RCT (8) N_{Start} =11 N_{End} =10 TPS=Chronic	E1: Anodal tDCS followed by peripheral nerve stimulation E2: Peripheral nerve stimulation followed by tDCS Duration: *Not Specified*	• Fugl-Meyer Assessment (-) • Stroke Impact Scale (-)
Sattler et al. (2015) RCT (7) N_{Start}=20 N_{End}=20 TPS=Acute	E: Repetitive peripheral nerve stimulation + anodal tDCS C: Repetitive peripheral nerve stimulation Duration: 20min/d, 5d/wk for 4wk	• Jebsen Hand Function Test (+exp) • Grip Strength (-) • 9 Hole Peg Test (-) • Hand Tapping Test (-) • Fugl-Meyer Assessment (-)
Dual tDCS with low frequency rTMS and mirror therapy		
D'Agata et al. (2016) RCT (6) N_{Start} =34 N_{End} =34 TPS=Chronic	E: Dual tDCS + low frequency (1Hz) rTMS + Mirror Therapy C: Sham tDCS + Mirror Therapy Duration: 1hr/wk, 5d/wk for 2wk	Action Research Arm Test (+exp)
Anodal or cathodal tDCS with virtual reality		
Lee et al. (2014) RCT (7) N_{Start}=64 N_{End}=59 TPS=Chronic	E1: cathodal tDCS E2: Virtual reality E3: Cathodal tDCS + virtual reality Duration: 90min/d, 3d/wk for 4wk	E1 vs E2 • Manual Function Test (+exp) • Fugl-Meyer Assessment (+exp) • Modified Barthel Index (-) • Manual Muscle Test (-) • Modified Ashworth Scale (-) • Box and Block Test (-) E3 vs E2/E1 • Manual Function Test (+exp$_3$) • Fugl-Meyer Assessment (+exp$_3$) • Modified Barthel Index (-) • Manual Muscle Test (-) • Modified Ashworth Scale (-) • Box and Block Test (-)
Viana et al. (2014) RCT (9)	E: Virtual reality + anodal tDCS C: Virtual reality + sham Duration: 1hr/d, 3d/wk for 5wk	• Fugl-Meyer Assessment (-) • Wolf Motor Function Test (-) • Modified Ashworth Scale (-)

N_{Start}=20 N_{End}=20 TPS=Chronic		• Grip strength (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about tDCS

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **anodal tDCS** to improve motor function when compared to **sham stimulation**.	11	Andrade et al. 2017; Marquez et al. 2017; Pavlova et al. 2017; Allman et al. 2016; Ilic et al. 2016; Mortensen et al. 2016; Sik et al. 2015; Hesse et al. 2011; Kim et al. 2010; Boggio et al. 2007; Fregni et al. 2005
1a	There is conflicting evidence about the effect of **cathodal tDCS** to improve motor function when compared to **sham stimulation or conventional therapy**.	9	Maquez et al. 2017; Rabadi et al. 2017; Lee et al. 2015; Fusco et al. 2014; Hesse et al. 2011; Kim et al. 2010; Boggio et al. 2007; Fregni et al. 2005
1a	**Dual tDCS** may produce greater improvements in motor function than **sham stimulation or conventional therapy**.	4	Koh et al. 2017; Sik et al. 2015; Cha et al. 2014; Lindenberg et al. 2010
1a	**Anodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving motor function.	3	Hesse et al. 2011; Boggio et al. 2007; Fregni et al. 2005
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **dual tDCS** for improving motor function.	1	Del Felice et al. 2017
1a	There is conflicting evidence about the effect of **anodal tDCS with CIMT** to improve motor function when compared to **sham tDCS with CIMT.**	3	Figlewski et al. 2016; Rocha et al. 2016; Cunningham et al. 2015
1b	**Cathodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving motor function.	1	Rocha et al. 2016
1b	**Dual tDCS with cyclic NMES and CIMT** may produce greater improvements in motor function than **CIMT**.	1	Takebayshi et al. 2017
1b	**Dual tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics** for improving motor function.	1	Straudi et al. 2016
1a	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics or upper limb robotics alone** for improving motor function.	2	Mazzoleni et al. 2017; Triccas et al. 2015
1b	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **cathodal tDCS with upper limb robotics** for improving motor function.	1	Ochi et al. 2013
1b	**Anodal or dual tDCS with brain computer interface-assisted motor imagery interventions** may not have a difference in efficacy when compared to **sham tDCS with brain computer interface-assisted motor imagery interventions** for improving motor function.	2	Hong et al. 2017; Ang et al. 2015

1b	**Dual tDCS with FES** may produce greater improvements in motor function than **sham tDCS with FES**.	1	Shaheiwola et al. 2018
1a	**Anodal tDCS with peripheral nerve stimulation** may not have a difference in efficacy when compared to **peripheral nerve stimulation** for improving motor function.	2	Powell et al. 2016; Sattler et al. 2015
1b	**Dual tDCS with low frequency rTMS and mirror therapy** may produce greater improvements in motor function than **sham tDCS with mirror therapy.**	1	D'Agata et al. 2016
1a	There is conflicting evidence about the effect of **anodal or cathodal tDCS with virtual reality training** to improve motor function when compared to **virtual reality training with or without sham tDCS.**	2	Lee et al. 2014; Viana et al. 2014
1b	**Cathodal tDCS** may produce greater improvements in motor function than **virtual reality training**.	1	Lee et al. 2014

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **anodal tDCS** to produce greater improvements on measures of stroke severity when compared to **sham stimulation**.	1	Khedr et al. 2013
1a	**Cathodal tDCS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improvements on measures of stroke severity.	2	Fusco et al. 2014; Khedr et al. 2013
1b	**Anodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improvements on measures of stroke severity.	1	Khedr et al. 2013
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **dual tDCS** for improvements on measures of stroke severity.	1	Del Felice et al. 2017

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **anodal tDCS** to improve dexterity when compared to **sham stimulation**.	5	Andrade et al. 2017; Pavlova et al. 2017; Kim et al. 2009; Au Yeung et al. 2014; Fusco et al. 2013
1a	**Cathodal tDCS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving dexterity.	3	Au Yeung et al. 2014; Fusco et al. 2014; Fusco et al. 2013
1a	**Dual tDCS** may produce greater improvements in dexterity than **sham stimulation or conventional therapy**.	5	Lefebvre et al. 2015; Cha et al. 2014; Lefebvre et al. 2014; Lefebvre et al. 2013; Fusco et al. 2013
1b	**Anodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving dexterity.	1	Cunningham et al. 2015
1a	**Dual tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics** for improving dexterity.	2	Dehem et al. 2018; Straudi et al. 2016
1b	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics or upper limb robotics alone** for improving dexterity.	1	Mazzoleni et al. 2017
1b	**Anodal tDCS with peripheral nerve stimulation** may not have a difference in efficacy when compared to **peripheral nerve stimulation** for improving dexterity.	1	Sattler et al. 2015
1b	**Anodal or cathodal tDCS with virtual reality training** may not have a difference in efficacy when compared to **virtual reality training with or without sham tDCS** for improving dexterity.	1	Lee et al. 2014
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **virtual reality training** for improving dexterity.	1	Lee et al. 2014

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Anodal tDCS** may produce greater improvements in spasticity than **sham stimulation**.	1	Andrade et al. 2017
1b	**Cathodal tDCS** may produce greater improvements in spasticity than **sham stimulation or conventional therapy**.	1	Wu et al. 2013
1a	**Dual tDCS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving spasticity.	2	Koh et al. 2017; Goodwill et al. 2016
1b	There is conflicting evidence about the effect of **cathodal tDCS** to improve spasticity when compared to **dual tDCS**.	1	Del Felice et al. 2017
1b	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics or upper limb robotics alone** for spasticity.	1	Mazzoleni et al. 2017
1b	**Anodal tDCS with upper limb robotics** may produce greater improvements in spasticity than **cathodal tDCS with upper limb robotics**.	1	Ochi et al. 2013
1b	**Dual tDCS with FES** may not have a difference in efficacy when compared to **sham tDCS with FES** for spasticity.	1	Shaheiwola et al. 2018
1a	**Anodal or cathodal tDCS with virtual reality training** may not have a difference in efficacy when compared to **virtual reality training with or without sham tDCS** for improving spasticity.	2	Lee et al. 2014; Viana et al. 2014
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **virtual reality training** for improving spasticity.	1	Lee et al. 2014

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **anodal tDCS** to improve performance of activities of daily living when compared to **sham stimulation**.	4	Andrade et al. 2017; Mortensen et al. 2016; Khedr et al. 2013; Kim et al. 2010
1a	There is conflicting evidence about the effect of **cathodal tDCS** to improve performance of activities of daily living when compared to **sham stimulation or conventional therapy**.	3	Fusco et al. 2014; Khedr et al. 2013; Kim et al. 2010
1b	**Dual tDCS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving performance of activities of daily living.	1	Koh et al. 2017
1b	**Anodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving performance of activities of daily living.	1	Khedr et al. 2013
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **dual tDCS** for improving performance of activities of daily living.	1	Del Felice et al. 2017
1a	**Anodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving performance of activities of daily living.	2	Rocha et al. 2016; Cunningham et al. 2015
1b	**Cathodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving performance of activities of daily living.	1	Rocha et al. 2016
1b	**Dual tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics** for improving performance of activities of daily living.	1	Straudi et al. 2016
1b	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics or upper limb robotics alone** for improving performance of activities of daily living.	1	Triccas et al. 2015
1b	**Anodal tDCS with upper limb robotics** may produce greater improvements in performance of activities of daily living than **cathodal tDCS with upper limb robotics**.	1	Ochi et al. 2013
1b	**Anodal tDCS with peripheral nerve stimulation** may not have a difference in efficacy when compared to **peripheral nerve stimulation** for improving performance of activities of daily living.	1	Powell et al. 2016
1b	**Anodal or cathodal tDCS with virtual reality training** may not have a difference in efficacy when compared to **virtual reality training with or without sham tDCS** for improving performance of activities of daily living.	1	Lee et al. 2014

1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **virtual reality training** for improving performance of activities of daily living.	1	Lee et al. 2014

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Anodal tDCS** may not have a difference in efficacy when compared to **sham stimulation** for improving muscle strength.	9	Andrade et al. 2017; Marquez et al. 2017; Ilic et al. 2016; Mortensen et al. 2016; Au Yeung et al. 2014; Fusco et al. 2013; Khedr et al. 2013; Stagg et al. 2012; Tanaka et al. 2011
1a	**Cathodal tDCS** may not have a difference in efficacy when compared to **sham stimulation or conventional therapy** for improving muscle strength.	6	Marquez et al. 2017; Au Yeung et al. 2014; Khedr et al. 2013; Fusco et al. 2013; Stagg et al. 2012; Zimmerman et al. 2012
1a	There is conflicting evidence about the effect of **dual tDCS** to improve muscle strength when compared to **sham stimulation or conventional therapy.**	4	Goodwill et al. 2016; Lefebvre et al. 2014; Fusco et al. 2013; Lefebvre et al. 2013
1a	**Anodal tDCS** may not have a difference in efficacy when compared to **cathodal tDCS** for improving muscle strength.	2	Khedr et al. 2013; Stagg et al. 2012
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **dual tDCS** for improving muscle strength.	1	Del Felice et al. 2017
1b	**Anodal tDCS with strength training** may not have a difference in efficacy when compared to **sham tDCS with strength training** for improving muscle strength.	1	Hendy et al. 2014
1a	**Anodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving muscle strength.	2	Figlewski et al. 2016; Rocha et al. 2016
1b	**Cathodal tDCS with CIMT** may not have a difference in efficacy when compared to **sham tDCS with CIMT** for improving muscle strength.	1	Rocha et al. 2016
1b	**Anodal tDCS with upper limb robotics** may not have a difference in efficacy when compared to **sham tDCS with upper limb robotics or upper limb robotics alone** for improving muscle strength.	1	Mazzoleni et al. 2017
1b	**Anodal tDCS with peripheral nerve stimulation** may not have a difference in efficacy when compared to **peripheral nerve stimulation** for improving muscle strength.	1	Sattler et al. 2015
1a	**Anodal or cathodal tDCS with virtual reality training** may not have a difference in efficacy when compared to **virtual reality training with or without sham tDCS** for improving muscle strength.	2	Lee et al. 2014; Viana et al. 2014
1b	**Cathodal tDCS** may not have a difference in efficacy when compared to **virtual reality training** for improving muscle strength.	1	Lee et al. 2014

Key points

The literature is mixed regarding anodal, cathodal, or dual transcranial direct current stimulation, alone or in combination with other therapy approaches, for upper limb rehabilitation following stroke.

Pharmaceuticals

Botulinum toxin

Adopted from: http://www.theinvestor.co.kr/view.php?ud=20180104000712

Botulinum toxin exerts a therapeutic effect by reducing overactivity in spastic muscles through blocking the release of acetylcholine at the neuromuscular junction. The benefits of botulinum toxin injections are generally dose-dependent and last approximately 2 to 4 months (Brashear et al. 2002; Francisco et al. 2002; Simpson et al. 1996; Smith et al. 2000). One of the advantages of botulinum toxin is that it is safe to use on small, localized areas or muscles, such as those in the upper extremity. Unlike chemodenervation and neurolytic procedures like phenol or alcohol, botulinum toxin is not associated with skin sensory loss or dysesthesia (Suputtitada & Suwanwela, 2005). Dynamic EMG studies can be helpful in determining which muscles should be injected (Bell & Williams, 2003).

Interventions for 35 RCTs using botulinum toxin included: 19 RCTs looked at botulinum toxin A compared to placebo (Rosales et al. 2018; Elovic et al. 2016; Gracies et al. 2015; Hesse et al. 2012; Marciniak et al. 2012; Wolf et al. 2012; Shaw et al. 2011; Kaji et al. 2010; Shaw et al. 2010; Meythaler et al. 2009; Simpson et al. 2009; Jahangir et al. 2007; Suputtitada and Suwanwela, 2005; Childers et al. 2004; Brashear et al. 2002; Bakheit et al. 2001; Bhakta et al. 2000; Smith et al. 2000; Simpson et al. 1996). Two RCTs looked at botulinum toxin B compared to placebo (Gracies et al. 2014; Brashear et al. 2004). One RCT looked at botulinum toxin A with upper limb rehabilitation compared to botulinum toxin A alone (Devier et al. 2017). Four RCTs looked at OnabotulinumtoxinA compared to letibotulinumtoxinA, NABOTA, Neurnox or tizanidine (Do et al. 2017; Nam et al. 2015; Seo et al. 2015; Simpson et al. 2009). A single RCT looked at high versus low dosage botulinum toxin A (Francisco et al. 2002). A single RCT looked at botulinum toxin A combined with adhesive taping versus botulinum toxin A combined with manual muscle stretching, passive articular mobilization, and palmar splinting (Santamato et al. 2015). Three RCTs looked at ultrasound guided botulinum toxin A injections versus other approaches (Zeuner et al. 2017; Picelli et al. 2014; Santamato et al. 2014). Two RCTs looked at botulinum toxin A combined with NMES (Marvulli et al. 2016; Hesse et al. 1998). A single RCT looked at botulinum toxin A combined with mCIMT compared to botulinum toxin A (Sun et al.

2010). Finally, a single RCT looked at botulinum toxin A combined with task-specific training compared to task-specific training alone (Umar et al. 2018).

The methodological details and results of all 35 RCTs evaluating rTMS for the upper extremity motor rehabilitation are presented in Table 31.

Table 31. RCTs evaluating botulinum toxin injections for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Botulinum toxin A versus placebo, no injection or conventional rehabilitation		
Rosales et al. (2018) RCT (7) N_{Start} =42 N_{End} =40 TPS=Subacute	E: Abobotulinumtoxin A 500U C: Placebo	• Modified Ashworth Scale (+exp) • Upper extremity active motor function (-)
Elovic et al. (2016) RCT (6) N_{Start}=317 N_{End}=299 TPS=Chronic	E: 400U incobotulinumtoxinA C: Placebo	• Ashworth Scale (+exp) • Disability Assessment Scale (+exp)
Gracies et al. (2015) RCT (8) N_{Start}=243 N_{End}=229 TPS=Chronic	E1: Single 500U AbobotulinumtoxinA E2: Single 1000U AbobotulinumtoxinA C: Placebo	E1/E2 vs. C • Modified Ashworth Scale (+exp, +exp$_2$) • Disability Assessment Scale (-)
Hesse et al. (2012) RCT (7) N_{start}=18 N_{end}=18 TPS=Acute	E: 150U Xeomin C: No injection	• Modified Ashworth Scale score (+exp) • Resistance to Passive Movement Scale (+exp) • Fugl-Meyer Assessment (-)
Marciniak et al. (2012) RCT (5) N_{Start}=21 N_{End}=19 TPS=Chronic	E: 100-150U of botulinum toxin type A (BTX-A) into the pectoralis major and teres major muscles in the shoulder extensors. C: Placebo	• Modified Ashworth Scale (-) • Passive range of motion (+exp) • Fugl-Meyer Assessment (+exp) • Functional Independence Measure (-) • Disability Assessment Scale (+exp)
Wolf et al. (2012) RCT (9) N_{start}=25 N_{end}=22 TPS=Chronic	E: 300U Botox (BTX-A) C: Placebo	• Wolf Motor Function test (-)
Shaw et al. (2011) RCT (8) N_{start}=333 N_{end}=329	E: 100-200 U Dysport + 4 weeks therapy C: Therapy only	• Action Research Arm Test (-) • Modified Ashworth Scale (+exp) • 9-Hole Peg Test (-) • Barthel Index (-)
Kaji et al. (2010) RCT (9) N_{start}=109 N_{end}=109 TPS=Chronic	E1: 120 U Botox (BoNTA) C1: Placebo E2: 200 U Botox (BoNTA) C2: Placebo	E2 vs C2 • Modified Ashworth Scale (+exp$_2$) • Disability Assessment Scale (+exp$_2$) E1 vs C1 • Modified Ashworth Scale (-) • Disability Assessment Scale (+exp$_1$)
Shaw et al. (2010) RCT (6)	E: Botulinum toxin type A (BTX-A, Dysport) injections + upper limb therapy	• Action Research Arm Test (-) • Modified Ashworth Scale (+exp)

N_{Start}=333 N_{End}=199 TPS=Subacute	C: Upper limb therapy	• Motricity Index (+exp) • Grip Strength (-) • 9-Hole Peg Test (-) • Barthel Index (-)
Meythaler et al. (2009) RCT (6) N_{start}=21 N_{end}=18 TPS=Chronic	E: 100 U Botox (BTX-A) + therapy C: Saline + therapy	• Motor Activity Log (-) • Ashworth Scale (-) • Barthel Index (-)
Simpson et al. (2009) RCT (8) N_{start}=60 N_{end}=41 TPS=Subacute	E1: Up to 500 U of BoNT-Type A E2: Tizanidine C: Placebo	E1 vs C • Modified Ashworth Scale (+exp) • Disability Assessment Scale (+exp) E2 vs C • Modified Ashworth Scale (-) • Disability Assessment Scale (-) E1 vs E2 • Modified Ashworth Scale (+exp) • Disability Assessment Scale ($+exp_1$)
Jahangir et al. (2007) RCT (6) N_{start}=27 N_{end}=27 TPS=Chronic	E: 50 U Botox (BTX-A) C: Placebo	• Modified Ashworth Scale (+exp) • Barthel Index (-)
Suputtitada & Suwanwela (2005) RCT (6) N_{start}=45 N_{end}=40 TPS=Chronic	E1: 350U BTX (Dysport) E2: 500U BTX (Dysport) E3: 1000U BTX (Dysport) C: Placebo	E1/E2/E3 vs C • Modified Ashworth Scale (+exp, $+exp_2$, $+exp_3$) E2/E3 vs C • Action Research Arm Test ($+exp_2$, $+exp_3$) E1/E2 vs C • Barthel Index (+exp, $+exp_2$)
Childers et al. (2004) RCT (7) N_{start}=91 N_{end}=91 TPS=Chronic	E1: 90U BTX (type A) E2: 180U BTX (type A) E3: 360U BTX (type A) C: Placebo	E1/E2/E3 vs C • Modified Ashworth Scale (+exp, $+exp_2$, $+exp_3$) • Functional Independence Measure (-)
Brashear et al. (2002) RCT (7) N_{start}=126 N_{end}=122 TPS=Chronic	E: Botulinum toxin A (50 U) C: Placebo	• Disability Assessment Scale (+exp) • Ashworth Scale (+exp)
Bakheit et al. (2001) RCT (8) N_{start}=59 N_{end}=58 TPS=Chronic	E: Total of 1000 IU of BtxA (Dysport) into 5 muscles of the affected arm C: Placebo injections	• Modified Ashworth Scale score (+exp) • Active/passive range of motion (-) • Barthel Index (-)
Bhakta et al. (2000) RCT (7) N_{start}=40 N_{end}=38 TPS=Chronic	E: Total of 1000 IU Dysport (n=20) C: Placebo (n=20) divided between elbow, wrist, and finger flexors	• Modified Ashworth Scale (+exp) • Active range of motion (-)
Smith et al. (2000) RCT (7) N_{start}=25 N_{end}=25 TPS=Chronic	E1: 500 U of botulinum toxin E2: 1000 U of botulinum toxin E3: 1500 U of botulinum toxin C: Placebo	E1/E2/E3 vs C • Modified Ashworth Scale at fingers ($+exp_{(combined)}$) • Active range of movement (-) • Frenchay Arm Test (-)

Simpson et al. (1996) RCT (8) N_{start}=37 N_{end}=37 TPS=Chronic	E1: Single treatment of 75 U BTX-A E2: 150 U BTX-A E3: 300 U BTXA C: Placebo	E1/E3 vs C • Modified Ashworth Scale (+exp$_1$, +exp$_3$) E1/E2/E3 vs C • Functional Independence Measure (-) • Fugl-Meyer Scale (-)
Botulinum toxin B versus placebo		
Gracies et al. (2014) RCT (9) N_{Start}=24 N_{End}=24 TPS=Chronic	E1: 10000 U Botox (type B) E2: 15000 U Botox (type B) C: Placebo	E1/E2 vs C • Modified Ashworth Scale (-) • Modified Frenchay Scale (-)
Brashear et al. (2004) RCT (7) N_{start}=15 N_{end}=15 TPS=Chronic	E: 10000 U of BTX-B C: Placebo	• Modified Ashworth scale (-)
Botulinum toxin A combined with upper limb rehabilitation versus botulinum toxin A		
Devier et al. (2017) RCT (5) N_{Start} =31 N_{End} =29 TPS=Chronic	E: OnabotulinumtoxinA with upper limb rehabilitation C: OnabotulinumtoxinA	• Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (-) • Disability Assessment Scale (-)
OnabotulinumtoxinA versus letibotulinumtoxinA, NABOTA, Neuronox, tizanidine		
Do et al. (2017) RCT (8) N_{Start} =187 N_{End} =169 TPS=Chronic	E: LetibotulinumtoxinA (Botulax) C: OnabotulinumtoxinA	• Modified Ashworth Scale (-) • Global Assessment in Spasticity (-) • Disability Assessment Scale (-)
Nam et al. (2015) RCT (7) N_{Start}=197 N_{End}=177 TPS=Subacute	E: Botulinum toxin type A (NABOTA) up to 360 U depending on degree of spasticity and muscle group C: Onabotulinum toxin A (Botox) up to 360 U depending on degree of spasticity and muscle group	• Modified Ashworth Scale (-) • Disability Assessment Scale (-)
Seo et al. (2015) RCT (10) N_{Start}=196 N_{End}=170 TPS=Chronic	E1: 360 U Neu-BoNT-A (Neuronox) E2: 360 U Botox	• Modified Ashworth Scale (-) • Disability Assessment Scale (-) •
Simpson et al. (2009) RCT (8) N_{start}=60 N_{end}=41 TPS=Subacute	E1: Up to 500 U of BoNT-Type A E2: Tizanidine C: Placebo	E1 vs C • Modified Ashworth Scale (+exp) • Disability Assessment Scale (+exp) E2 vs C • Modified Ashworth Scale (-) • Disability Assessment Scale (-) E1 vs E2 • Modified Ashworth Scale (+exp) • Disability Assessment Scale (+exp)
High versus low dosage botulinum toxin A		
Francisco et al. (2002) RCT (7) N_{start}=13 N_{end}=9 TPS=Acute	E1: High volume BTX-A (50 units/1 mL saline: 1.2 mL delivered per muscle) E2: Low volume BTX-A (100 units/1 mL saline: 0.6 mL delivered per muscle)	• Modified Ashworth Scale: (-)
Botulinum toxin A combined with adhesive taping versus botulinum toxin A combined with manual muscle stretching, passive articular mobilization, and palmar splinting		

Santamato et. al (2015) RCT (7) N_{Start}=70 N_{End}=70 TPS=Chronic	E: 50-200 U Botox (type A) + adhesive taping for 10d C: 50-200 U Botox (type A) + manual muscle stretching, passive articular mobilization, and palmar splint	• Modified Ashworth Scale (+exp) • Disability Assessment Scale (+exp)
Ultrasound guided botulinum toxin A injections		
Zeuner et al. (2017) RCT-Crossover (5) N_{Start} =30 N_{End} =23 TPS=Chronic	E: Ultrasound guided Botulinum Toxin A Injections followed by electromyographic (EMG) Guided Botulinum Toxin A Injections (100-400mu) C: EMG Guided Botulinum Toxin A Injections followed by Ultrasound Guided Botulinum Toxin A Injections (100-400mu)	• Modified Ashworth Scale (-) • Barthel Index (-) • Disability Assessment Scale (-)
Picelli et al. (2014) RCT (8) N_{Start}=60 N_{End}=60 TPS=Chronic	E1: Botox A Injections (500u) under sonographic guidance E2: Botox A Injection (500u) using electrical stimulation guidance C: Botox A Injection (500u) using manual needle placement	E1 vs C • Modified Ashworth Scale (+exp) • Tardieu Spasticity angle (+exp) • Passive range of motion (+exp) E2 vs C • Modified Ashworth Scale (wrist): (+exp$_2$) • Tardieu Spasticity angle (+exp$_2$) • Passive range of motion (+exp$_2$) E1 vs E2 • Modified Ashworth Scale (-) • Tardieu Spasticity angle (-) • Passive range of motion (-)
Santamato et al. (2014) RCT (4) N_{Start}=30 N_{End}=30 TPS=Chronic	E: BoNT-A injection using ultrasound guidance (dosages determined by investigator) C: BoNT-A using manual needle placement via palpitation and anatomical landmarks (dosages determined by investigator)	• Modified Ashworth Scale (+exp)
Botulinum toxin A combined with NMES		
Marvulli et al. (2016) RCT (6) N_{Start}=36 N_{End}=36 TPS=Chronic	E: Botulinum toxin A therapy (118±34 U) + occupational therapy (OT) + functional electrical stimulation C: Botulinum toxin A therapy (116±36 U) + OT Duration: *Not Specified*	• Modified Ashworth Scale (+exp) • Passive range of Motion (+exp) • Action Research Arm Test (+exp)
Hesse et al. (1998) RCT (7) N_{start}=24 N_{end}=24 TPS=Chronic	E1: 1000 U Btx A + cyclic NMES E2: 1000 U of Btx A E3: Placebo + cyclic NMES C: Placebo Duration: Daily injections for 3 mo For electrical stimulation: 30 min/d, 2d/wk for 4 wk	E1 vs E2 vs E3 vs C • Modified Ashworth Scale (-) E1 vs E2/C • Reduction in difficulties with cleaning palm (+exp)
Botulinum toxin A combined with mCIMT		
Sun et al. (2010) RCT (6) N_{start}=32 N_{end}=32 TPS=Chronic	E: 1,000 U Dysport + mCIMT C: 1,000 U Dysport + conventional rehabilitation Duration : 2hr/d, 3d/wk for 3 mo	• Modified Ashworth Scale (+exp) • Motor Activity Log (+exp) • Action Research Arm Test (+exp)
Botulinum toxin A combined with task-specific training versus task-specific training		

Umar et al. (2018) RCT (5) N_{Start} =46 N_{End} =41 TPS=NR	E: Botulinum Toxin A with Task-Specific Training C: Task-Specific Training	• Fugl-Meyer Assessment (-) • Motor Assessment Scale (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about botulinum toxin

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Botulinum toxin A** may not have a difference in efficacy when compared to **placebo, no injection or conventional therapy** for improving motor function.	8	Rosales et al. 2018; Hesse et al. 2012; Marciniak et al. 2012; Wolf et al. 2012; Shaw et al. 2011; Shaw et al. 2010; Suputtitada and Suwanwela, 2005; Simpson et al. 1996
2	**Botulinum toxin A combined with upper limb rehabilitation** may produce greater improvements in motor function than **botulinum toxin A alone**.	1	Devier et al. 2017
1b	**Botulinum toxin A combined with functional electrical stimulation** may produce greater improvements in motor function than **botulinum toxin A**.	1	Marvulli et al. 2016
1b	**Botulinum toxin A combined with mCIMT** may produce greater improvements in motor function than **botulinum toxin A**.	1	Sun et al. 2010
2	**Botulinum toxin A combined with task-specific training** may not have a difference in efficacy when compared to **task-specific training alone** for improving motor function.	1	Umar et al. 2018

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Botulinum toxin A** may not have a difference in efficacy when compared to **placebo, no injection or conventional therapy** for improving performance of activities of daily living.	10	Marcinak et al. 2012; Shaw et al. 2011; Shaw et al. 2010; Meythaler et al. 2009; Jahangir et al. 2007; Suputtiada & Suwanwela, 2005; Childers et al. 2004; Bakheit et al. 2001; Smith et al. 2000; Simpson et al. 1996
1b	**Botulinum toxin B** may not have a difference in efficacy when compared to **placebo** for improving performance of activities of daily living.	1	Gracies et al. 2014
2	**Ultrasound guided botulinum toxin A injections** may not have a difference in efficacy when compared to **electromyography guided botulinum toxin A injections** for improving performance of activities of daily living.	1	Zeuner et al. 2017
1b	**Botulinum toxin A combined with mCIMT** may produce greater improvements in performance of activities of daily living than **botulinum toxin A**.	1	Sun et al. 2010
2	**Botulinum toxin A combined with task-specific training** may not have a difference in efficacy when compared to **task-specific training alone** for improving performance of activities of daily living.	1	Umar et al. 2018

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Botulinum toxin A** may not have a difference in efficacy when compared to **placebo, no injection or conventional therapy** for improving dexterity.	2	Shaw et al. 2011; Shaw et al. 2010

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Botulinum toxin A** may not have a difference in efficacy when compared to **placebo, no injection or conventional therapy** for improving range of motion.	4	Marciniak et al. 2012; Bakheit et al. 2001; Bhakta et al. 2000; Smith et al. 2000
1b	**Ultrasound guided botulinum toxin A injections** may produce greater improvements in range of motion than **manual needle placement injections**.	1	Picelli et al. 2014
1b	**Electrical stimulation guided botulinum toxin A injections** may produce greater improvements in range of motion than **manual needle placement injections**.	1	Picelli et al. 2014
1b	**Ultrasound guided botulinum toxin A injections** may not have a difference in efficacy when compared to **electrical stimulation guided botulinum toxin A injections** for improving range of motion.	1	Picelli et al. 2014
1b	**Botulinum toxin A combined with functional electrical stimulation** may produce greater improvements in range of motion than **botulinum toxin A**.	1	Marvulli et al. 2016

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Botulinum toxin A** may produce greater improvements in muscle strength than **placebo, no injection or conventional therapy**.	1	Shaw et al. 2010

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Botulinum toxin A** may produce greater improvements in spasticity than **placebo, no injection or conventional therapy**.	18	Rosales et al. 2018; Elovic et al. 2016; Gracies et al. 2015; Hesse et al. 2012; Marciniak et al. 2012; Shaw et al. 2011; Kaji et al. 2010; Shaw et al. 2010; Meythaler et al. 2009; Simpson et al. 2009; Jahangir et al. 2007; Suputtitada and Suwanwela, 2005; Childers et al. 2004; Brashear et al. 2002; Bakheit et al. 2001; Bhakta et al. 2000; Smith et al. 2000; Simpson et al. 1996
1a	**Botulinum toxin B** may not have a difference in efficacy when compared to **placebo** for improving spasticity.	2	Gracies et al. 2014; Brashear et al. 2004
2	**Botulinum toxin A combined with upper limb rehabilitation** may not have a difference in efficacy when compared to **botulinum toxin A alone** for improving spasticity.	1	Devier et al. 2017
1b	**LetibotulinumtoxinA, NABOTA and neuronox** may not have a difference in efficacy when compared to **onabotulinumtoxinA** for improving spasticity.	3	Do et al. 2017; Nam et al. 2015; Seo et al. 2015
1b	**Botulinum toxin A** may produce greater improvements in spasticity than **tizanidine**.	1	Simpson et al. 2009
1b	**High volume botulinum toxin A** may not have a difference in efficacy when compared to **low volume botulinum toxin A** for improving spasticity.	1	Francisco et al. 2002
1b	**Botulinum toxin A combined with adhesive taping** may produce greater improvements in spasticity than **botulinum toxin A combined with manual muscle stretching, passive articular mobilization, and palmar splinting**.	1	Santamato et al. 2015
2	**Ultrasound guided botulinum toxin A injections** may not have a difference in efficacy when compared to **electromyography guided botulinum toxin A injections** for improving spasticity.	1	Zeuner et al. 2017
1b	**Ultrasound guided botulinum toxin A injections** may produce greater improvements in spasticity than **manual needle placement injections**.	2	Santamato et al. 2014; Picelli et al. 2014
1b	**Electrical stimulation guided botulinum toxin A injections** may produce greater improvements in spasticity than **manual needle placement injections**.	1	Picelli et al. 2014
1b	**Ultrasound guided botulinum toxin A injections** may not have a difference in efficacy when compared to **electrical stimulation guided botulinum toxin A injections** for improving spasticity.	1	Picelli et al. 2014
1b	**Botulinum toxin A combined with functional electrical stimulation** may produce greater improvements in spasticity than **botulinum toxin A**.	1	Marvulli et al. 2016

1b	**Botulinum toxin A combined with cyclic NMES** may not have a difference in efficacy when compared to **botulinum toxin A, cyclic NMES, or placebo** for improving spasticity.	1	Hesse et al. 1998
1b	**Botulinum toxin A combined with mCIMT** may produce greater improvements in spasticity than **botulinum toxin A**.	1	Sun et al. 2010

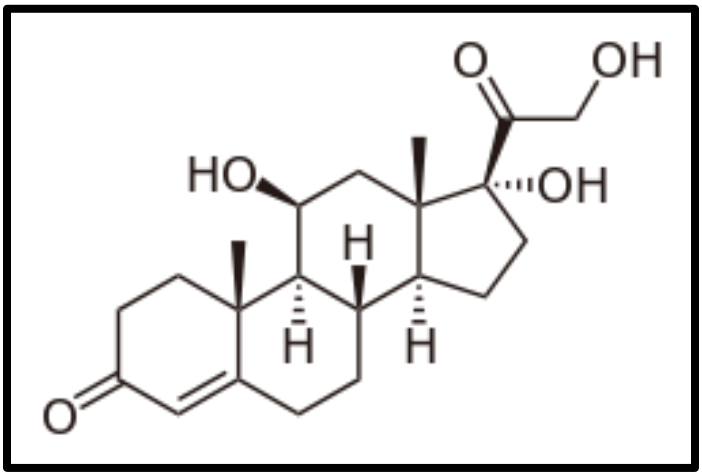
Key points

Botulinum A likely improves spasticity in the upper limb following stroke, but not range of motion or activities of daily living. The effect on general upper limb motor function is conflicting and less clear.

Botulinum toxin A in combination with other types of therapeutic approaches may be beneficial for certain aspects of upper limb function.

Botulinum toxin B has been less well studied to date in comparison to botulinum toxin A.

Steroids



Adopted from: https://en.wikipedia.org/wiki/Corticosteroid

Corticosteroids have been used to treat pain and functional limitations in hemiplegic patients (Dogan et al. 2013). Patients suffering from stroke experience high rates of inflammation and corticosteroids are prescribed to lessen the inflammation (Yasar et al. 2011).

The methodological details and results of a single RCT evaluating intra-articular steroid use for upper extremity motor rehabilitation are presented in Table 32.

Table 32. RCT intra-articular steroid use for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Yasar et al. (2011) RCT (9) N_{Start}=26 N_{End}=26 TPS=Subacute	E1: Intra-Articular Steroid Injection E2: Suprascapular Nerve Block Injection Duration: *Not Specified*	• Range of Motion (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about steroids

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Intra-articular steroid injections** may not have a difference in efficacy when compared to **suprascapular nerve block injections** for improving range of motion.	1	Yasar et al. 2011

Key points

Steroid injections may not be beneficial for upper limb rehabilitation following stroke.

Cerebrolysin

Adopted from: http://www.gerovitalshop.eu/it/home/18-cerebrolysin-5ml.html

Cerebrolysin contains low molecular weight neuropeptides and free amino acids which are believed to have neuroprotective properties, inhibit free radical formation, reduce neuroinflammation, and activate calpain apoptosis (Muresanu et al. 2016). The methodological details and results of two RCTs evaluating cerebrolysin for upper extremity motor rehabilitation are presented in Table 33.

Table 33. RCTs evaluating cerebrolysin for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Chang et al. (2016) RCT (6) N_{start}=70 N_{end}=66 TPS=Acute	E: Cerebrolysin (30mL diluted with 70mL saline) + conventional therapy C: Placebo + conventional therapy Duration: 1x/d for 6wk	• Action Research Arm Test (+exp) • National Institute of Health Stroke Scale (+exp) • Barthel Index (+exp) • Modified Rankin Scale (+exp)
Muresanu et al. (2016) RCT (9) N_{start}=208 N_{end}=196 TPS=Acute	E: Cerebrolysin (30mL diluted with 70mL saline) + physical/occupational therapy C: Placebo + physical/occupational therapy Duration: 1x/d for 3wk	• Fugl-Meyer Assessment (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about cerebrolysin

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Cerebrolysin** may produce greater improvements in motor function than **placebo**.	2	Chang et al. 2016; Muresanu et al. 2016

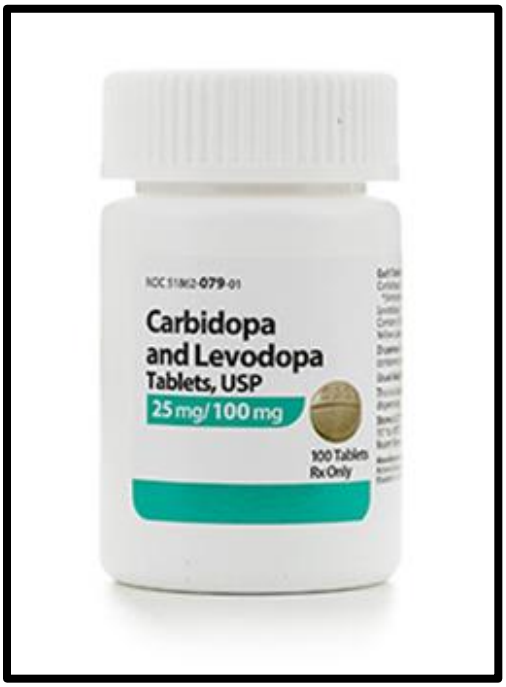
ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Cerebrolysin** may produce greater improvements in range of motion than **placebo**.	1	Chang et al. 2016

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Cerebrolysin** may produce greater improvements in measures of stroke severity than **placebo**.	1	Chang et al. 2016

Key points

Cerebrolysin may be beneficial for aspects of upper limb function following stroke.

Levodopa



Adopted from: https://www.maynepharma.com/products/us-products/generic-products/generic-products-catalog/carbidopalevodopa-tablets/

Levodopa has been the hallmark pharmaceutical for the treatment of Parkinson's disease. However, its ability to affect motor movements in Parkison's disease is limited by its narrow therapeutic window, short half-life, and poor bioavailability (Tambassco et al. 2018).

The methodological details and results of two RCTs evaluating levodopa treatment for upper extremity motor rehabilitation in stroke survivors are presented in Table 34.

Table 34. RCTs evaluating levodopa interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Rosser et al. (2008) RCT (5) N_{start}=18 N_{end}=18 TPS=Chronic	E: Levodopa (100mg) + Cabidopa (25mg) C: Placebo (125mg) Duration: 1hr physio (3x) + Levodopa (3x)	• Performance in a simple motor task (+exp)
Restemeyer et al. (2007) RCT (9) N_{start}=10 N_{end}=10 TPS=Chronic	E: Levodopa (100mg) C: Placebo (100mg) Duration: 1hr physio (2x) + Levodopa (2x)	• Nine Hole Peg Test (-) • Grip strength (-) • Action Research Arm Test (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about levodopa

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **Levodopa** to improve motor function when compared to **placebo**.	2	Rosser et al. 2008; Restemeyer et al. 2007

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Levodopa** may not have a difference in efficacy when compared to **placebo** for improving muscle strength.	1	Restemeyer et al. 2007

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Levodopa** may not have a difference in efficacy when compared to **placebo** for improving dexterity.	1	Restemeyer et al. 2007

Key points

The evidence is mixed regarding Levodopa for upper limb rehabilitation following stroke.

Atorvastatin

Adopted from: https://www.aarp.org/health/drugs-supplements/info-2016/new-guidelines-on-who-should-take-statins-cs.html

HMG-CoA reductase inhibitors (statins) are widely used worldwide due to their anti-atherosclerotic, anti-inflammatory, and immunomodulatory properties (Lin et al. 2015). This suggests that statins may have a beneficial role in infection, in fact, statins are found to have beneficial effects on the prevention and treatment of infections in diseases including cerebrovascular accidents (Lin et al. 2015). Statins are also believed to have a neuroprotective effect and are conducive to promoting autophagy in neurological disorders (Lin et al. 2015).

The methodological details and results of a single RCTs evaluating atorvastatin for upper extremity motor rehabilitation are presented in Table 35.

Table 35. RCT evaluating atorvastatin use for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Zhang et al. (2017) RCT (6) N_{Start}=78 N_{End}=75 TPS=Acute	E: Atorvastatin (20mg) C: Placebo (20mg) Duration: Atorvastatin daily for 6wk	• Modified Rankin Scale (+exp) • Barthel Index (+exp) • NIHSS (-)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about atorvastatin

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Atorvastatin** may produce greater improvements in activities of daily living than **placebo**.	1	Zhang et al. 2017

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **atorvastatin** to improve motor function when compared to **placebo**.	1	Zhang et al. 2017

Key points

The evidence is mixed regarding atorvastatin for upper limb rehabilitation following stroke.

Antidepressants

Adopted from: https://www.newportacademy.com/resources/treatment/teens-antidepressants-side-effects-risks-holistic-treatment/

Antidepressants of various kinds are available for medical use, including tricyclics (TCAs), monoamine oxidase inhibitors (MAOIs), selective serotonin reuptake inhibitors (SSRIs), serotonin-noradrenaline reuptake inhibitors (SNRIs, such as venlafaxine, duloxetine and milnacipran), and other agents (mirtazapine, reboxetine, bupropion). SSRIs and SNRIs are two commonly prescribed agents that work by acting to inhibit the reuptake of serotonin and norepinephrine, respectively, from the synaptic cleft (Cipriani et al. 2012). Beyond their ability to improve depression following stroke, antidepressants can be used to enhance upper extremity motor recovery through changes in neurotransmission. There is evidence suggesting that serotoninergic modulation may be involved in motor recovery post stroke. Previous research has suggested that patients who have reacted well to antidepressant treatment may also demonstrate improvements in upper limb motor functioning (Chemerinski et al. 2001). Furthermore, there are reports that single doses of selective serotonin reuptake inhibitors (SSRIs), such as fluoxetine and paroxetine, have resulted in activation of the motor cortices (Dam et al. 1996; Pariente et al. 2001) therefore, manipulation of neurochemicals may influence aspects of function other than psychological distress. Moreover, there is evidence to suggest that noradrenergic reuptake inhibitors (NRIs) increase motor cortex excitability (Plewnia et al. 2002).

The methodological details and results of 7 RCTs evaluating antidepressants for upper extremity motor rehabilitation are presented in Table 36.

Table 36. RCTs evaluating antidepressants interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Ward et al. (2017) RCT (7) N_{Start} =12 N_{End} =9 TPS=Chronic	E: Atomoxetine 40 mg with Task-Oriented Upper Extremity Training C: Placebo with Task-Oriented Upper Extremity Training	• Fugl-Meyer Assessment (+exp) • Action Research Arm Test (-) • Wolf Motor Function Test (-)
Mohammadianinejad et al. (2014) RCT (6) N_{Start}=80 N_{End}=66 TPS=Acute	E: Lithium carbonate (300mg) C: Placebo Duration: Lithium Carbonate 300mg (2x/d) for 30d	• National Institutes of Health Stroke Scale (+exp) • Fugl-Meyer Assessment (+exp)
Chollet et al. (2011) RCT (9) N_{start}=118 N_{end}=113 TPS=Chronic	E: Fluoxetine (20mg) C: Placebo Duration: Ingested daily (orally) for 3mo	• Fugl Meyer Assessment (+exp) • National Institutes of Health Stroke Scale (-) • Modified Rankin Scale (+exp)
Zittel et al. (2008) RCT (8) N_{start}=8 N_{end}=8 TPS=Chronic	E: Citalopram (40mg) C: Placebo (40mg) Duration: Citalopram (2x)	• Nine Hole Peg Test (+exp) • Hand grip strength (-)
Zittel et al. (2007) RCT (6) N_{start}=10 N_{end}=10 TPS=Chronic	E: Reboxetine (6mg) C: Placebo (6mg) Duration: Reboxetine (2x)	• Tapping speed (+exp) • Grip strength (+exp)
Notriptyline + Fluoxetine versus Placebo		
Mikami et al. (2011) RCT (8) 1 yr follow-up analysis of Robinson et al. 2000 N_{start}=104 N_{end}=97 TPS=Chronic	E1: Nortriptyline (100mg) E2: Fluoxetine (40mg) C: Placebo Duration: Fluoxetine or Nortriptyline daily for 12wk	E1/E2 vs C • Modified Rankin Scale (+exp$_1$, +exp$_2$)
Robinson et al. (2000) RCT (8) N_{start}=104 N_{end}=97 TPS=Chronic	E1: Nortriptyline (100mg) E2: Fluoxetine (40mg) C: Placebo Duration: Fluoxetine or Nortriptyline daily for 12wk	E1 vs E2/C • Functional Independence Measure (+exp$_1$)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about antidepressants

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **antidepressants** to improve motor function when compared to **placebo treatment**.	3	Ward et al. 2017; Mohammadianinejad et al. 2014; Chollet et al. 2011

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **antidepressants** to improve muscle strength when compared to **placebo treatment**.	2	Zittel et al. 2008; Zittel et al. 2007

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Antidepressants** may produce greater improvements in performance of activities of daily living than **placebo treatment**.	1	Robinson et al. 2000

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Antidepressants** may produce greater improvements in dexterity than **placebo treatment**.	2	Zittel et al. 2008; Zittel et al. 2007

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Antidepressants** may produce greater improvements in measures of stroke severity than **placebo treatment**.	3	Mohammadianinejad et al. 2014; Chollet et al. 2011; Mikami et al. 2011

Key points

Antidepressants may be beneficial for aspects of upper limb function following stroke.

Central nervous system stimulants

Adopted from: https://www.narconon.org/drug-information/amphetamine-health-risks.html

Central nervous system stimulants are drugs that increase cortical excitability, often provided to manage arousal states by enhancing neural transmission. Central nervous system stimulants increase the synaptic concentration and transmission of dopamine, serotonin, and noradrenaline throughout the brain, and neurobehavioral gains ascribed to central nervous system stimulants include enhanced arousal, mental processing speed, and/or motor processing speed (Herrold et al. 2014). Common stimulants used in rehabilitation include amphetamines and methylphenidates. Methylphenidate has been shown to enhance motor recovery after partial cortex ablation in rodents, and to modulate poststroke cerebral reorganization, improving motor function in stroke patients (Wang et al. 2014). Stimulants such as amphetamines have been reported to enhance plasticity through axonal sprouting (Papadopoulos et al. 2009).

The methodological details and results of four RCTs evaluating antidepressants for upper extremity motor rehabilitation are presented in Table 37.

Table 37. RCTs evaluating meridian acupressure and massage therapy interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Schuster et al. (2011) RCT (9) N_{start}=16 N_{end}=15 TPS=Chronic	E: Dexamphetamine (10mg) C: Placebo Duration: 20min/d, 2d/wk for 5wk	• Chedoke-McMaster Stroke Assessment (+exp)
Tardy et al. (2006) RCT (9) N_{start}=8 N_{end}=8 TPS=Chronic	E: Methylphenidate (20mg) C: Placebo Duration: 2d/wk for 4wk	• Finger tapping scores (+exp) • Hand grip strength (-)
Platz et al. (2005a) RCT (9) N_{start}=31 N_{end}=29 TPS=Chronic	E: d-amphetamine (10mg) C: Placebo Duration: 45min/d, 3d/wk for 4wk	• TEMPA (+exp)
Methylphenidate + tDCS		
Wang et al. (2014) RCT (7) N_{start}=9 N_{end}=9 TPS=Subacute	E1: Dual tDCS + methylphenidate (20mg) E2: Dual tDCS + placebo drug E3: Sham tDCS + methylphenidate C: Sham tDCS + placebo drug Duration: 20min/d, 3d/wk for 4wk	E1 vs E2/E3 • Purdue Pegboard Test: (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about central nervous stimulants

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Dexamphetamine and methylphenidate** may produce greater improvements in motor function than **placebo treatment**.	2	Schuster et al. 2011; Platz 2005a

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Dexamphetamine and methylphenidate** may not have a difference in efficacy when compared to **placebo treatment** for improving muscle strength.	1	Tardy et al. 2006

DEXTERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	**Dexamphetamine and methylphenidate** may produce greater improvements in dexterity than **placebo treatment**.	1	Tardy et al. 2006
1b	**Methylphenidate combined with dual tDCS** may produce greater improvements in dexterity than **dual tDCS or methylphenidate**.	1	Wang et al. 2014

Key points

Dexamphetamine or methylphenidate may be beneficial for aspects of upper limb function following stroke.

Methylphenidate combined with dual transcranial direct current stimulation may be beneficial for upper limb rehabilitation following stroke.

Complementary and alternative medicine

Acupuncture

Adopted from: https://www.mccaffreyhealth.com/acupuncture-for-chronic-pain/

The use of acupuncture has recently gained attention as an adjunct to stroke rehabilitation in Western countries even though acupuncture has been a primary treatment method in China for about 2000 years (Baldry, 2005). In China, acupuncture is an acceptable, time-efficient, simple, safe and economical form of treatment used to ameliorate motor, sensation, verbal communication and further neurological functions in post-stroke patients," (Wu et al., 2002). According to Rabinstein and Shulman (2003), "Acupuncture is a therapy that involves stimulation of defined anatomic locations on the skin by a variety of techniques, the most common being stimulation with metallic needles that are manipulated either manually or that serve as electrodes conducting electrical currents". There is a range of possible acupuncture mechanisms that may contribute to the health benefits experienced by stroke patients (Park et al. 2006). For example, acupuncture may stimulate the release of neurotransmitters (Han & Terenius, 1982) and have an effect on the deep structure of the brain (Wu et al. 2002). Lo et al. (2005) established acupuncture, when applied for at least 10 minutes, led to long-lasting changes in cortical excitability and plasticity even after the needle stimulus was removed. With respect to stroke rehabilitation, the benefit of acupuncture has been evaluated most frequently for pain relief and recovery from hemiparesis.

18 RCTs for acupuncture were identified. In 11 RCTs Acupuncture was compared to sham or conventional rehabilitation (Chen et al. 2016; Liu et al. 2016; Cui et al. 2014; Bai et al. 2013; Zhuangl et al. 2012; Wayne et al. 2005; Alexander et al. 2004; Sze et al. 2002; Kiendhal et al. 1997; Hu et al. 1993; Naeser et al. 1992). Four RCTs looked at comparisons of different acupuncture techniques (Ni et al. 2013; Fragoso and Ferreira, 2012; Zhao et al. 2009; Gosman-Hedstom et al. 1998). RCTs looked at acupuncture combined with CIMT (Song et al. 2016), TENS (Hopwood et al. 2008). Finally, a single RCT looked at acupuncture compared to cerebroprotein hydrolysate and piracetam (Han et al. 2015).

The methodological details and results of all 18 RCTs evaluating acupuncture for upper extremity motor rehabilitation are presented in Table 38.

Table 38. Summary of RCTS with Examining Acupuncture for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Acupuncture compared to conventional therapy or sham		
Chen et al. (2016) RCT (8) N_{Start}=250 N_{End}=250 TPS=Chronic	E: Acupuncture C: Conventional therapy Duration: 45min/d, 6d/wk for 3wk	• National Institute of Health Stroke Scale (+exp) • Fugl-Meyer Assessment (+exp)
Liu et al. (2016) RCT (6) N_{Start}=38 N_{End}=31 TPS=Chronic	E: Manual acupuncture + standard care C: Standard care Duration: *Not Specified*	• National Institute of Health Stroke Scale (-) • Fugl-Meyer Assessment (-) • Functional Independence Measure (-) • Barthel Index (-) • Modified Rankin Scale (-)
Cui et al. (2014) RCT (6) N_{Start}=60 N_{End}=60 TPS=NR	E: Yin Yang manipulation C: Conventional needling manipulation Duration: *Not Specified*	• Elbow spasm (+exp) • Clinical Spasticity Index (+exp)
Bai et al. (2013) RCT (9) N_{Start}=120 N_{End}=120 TPS=NR	E1: Acupuncture E2: Physical therapy E3: Acupuncture + physical therapy Duration: *Not Specified*	E1 vs E2 • Fugl-Meyer Assessment (-) • Modified Barthel Index (-) E1 vs E3 • Fugl-Meyer Assessment (-) • Modified Barthel Index (-) E2 vs E3 • Fugl-Meyer Assessment (-) • Modified Barthel Index (-)
Zhuangl et al. (2012) RCT (7) N_{start}=295 N_{end}=274 TPS=Chronic	E1: Acupuncture E2: Physiotherapy E3: Acupuncture + physiotherapy Duration: 1hr/d, 6d/wk for 4wk	• Fugl-Meyer Assessment (-) • Barthel Index (-) • Neurologic Defect Scale (-)
Wayne et al. (2005) RCT (9) N_{start}=33 N_{end}=33 TPS=Chronic	E: Acupuncture C: Sham Duration: 45min/d, 2d/wk for 10wk	• Fugl-Meyer Assessment (-) • Modified Ashworth scores (-) • Arm range of motion (-) • Barthel Index (-)
Alexander et al. (2004) RCT (6) N_{start}=32 N_{end}=28 TPS=Acute	E: Acupuncture + Standard Rehabilitation C: Standard Rehabilitation Duration: 30min/d, 2d/wk for 10 wk	• Fugl-Meyer Assessment (-) • Functional Independence Measure (-)
Sze et al. (2002) RCT (7) N_{start}=106 N_{end}=106 TPS=Acute	E: Acupuncture + Standard Therapy C: Standard Therapy Duration: 45min/d, 2d/wk for 10wk	• Fugl-Meyer Assessment (-) • Barthel Index (-) • Functional Independence Measure (-) • National Institutes of Health Stroke Scale (-)

Kjendhal et al. (1997) RCT (6) N_{start}=45 N_{end}=41 TPS=Subacute	E: Acupuncture C: Standard Therapy Duration: 30min/d, 3-4d/wk for 6wk	• Motor Assessment Scale (+exp) • Sunnaas Index (+exp)
Hu et al. (1993) RCT (4) N_{start}=30 N_{end}=NR TPS=Acute	E: Acupuncture C: Supportive Therapy + Conventional Rehabilitation Duration: *Not Specified*	• Scaninavian stroke study Neurological score (+exp) • Barthel Index (-)
Naeser et al. (1992) RCT (6) N_{start}=16 N_{end}=16 TPS=Subacute	E: Acupuncture C: Sham Acupuncture Duration: 1hr/d, 5d/wk for 4wk	• Boston Motor Inventory range of motion (+exp)
Acupuncture vs acupuncture		
Ni et al. (2013) RCT (7) N_{Start}=165 N_{End}=165 TPS=NR	E: Standard Acupuncture with Shixuan & Xiaohai acupoints C: Standard Acupuncture only Duration: *Not Specified*	• Finger grip strength (+exp) • Fugl-Meyer Assessment (+exp)
Fragoso & Ferreira (2012) RCT (6) N_{start}=32 N_{end}=32 TPS=Chronic	E1: Acupuncture at Tianquan (PC2) E2: Acupuncture at Quchi (LI11) Duration: 20min/d, 5d/wk for 4wk	• Maximal Isometric Voluntary Contraction during elbow flexion (-)
Zhao et al. (2009) RCT (5) N_{start}=131 N_{end}=120 TPS=Chronic	E: Experimental acupuncture C: Traditional acupuncture Duration: 20min/d, 7d/wk, for 4wk	• Modified Ashworth Scale (+exp) • Fugl-Meyer Assessment (+exp) • Barthel Index (+exp)
Gosman-Hedstom et al. (1998) RCT (7) N_{start}=104 N_{end}=98 TPS=Acute	E1: Superficial acupuncture E2: Deep acupuncture C: No acupuncture Duration: 1hr/d, 2d/wk for 10 wk	E1 vs E2 vs C • Scaninavian stroke study Neurological score (-) • Barthel Index (-) • Sunnaas Index (-)
Acupuncture combined with CIMT		
Song et al. (2016) RCT (5) N_{Start}=30 N_{End}=30 TPS=Acute	E: Scalp cluster acupuncture + constraint-induced movement therapy C: Body acupuncture + traditional rehabilitation Duration: 6hr/d, (needles twisted 2-3x), 6d/wk for 2wk	• Fugl-Meyer Assessment (-)
Acupuncture combined with TENS		
Hopwood et al. (2008) RCT (7) N_{start}=105 N_{end}=105 TPS=Acute	E: Acupuncture with TENS C: Acupuncture with sham TENS Duration: 1hr/d, 3d/wk for 4wk	• Barthel Index (-) • Motricity Index (-)
Acupuncture versus cerebroprotein hydrolysate and piracetam		
Han et al. (2015) RCT (6) N_{Start}=488 N_{End}=488 TPS=NR	E: Meridian sinew row needling combined with dermal needling C: Cerebroprotein hydrolysate (20mL) and piracetam injections (4g) Duration: *Not Specified*	• Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.

+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp_2 indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about acupuncture

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Acupuncture** may not have a difference in efficacy when compared to **conventional therapy or sham** for improving motor function.	8	Chen et al. 2016; Liu et al. 2016; Han et al. 2015; Bai et al. 2013; Zhuangl et al. 2012; Wayne et al. 2005; Alexander et al. 2004; Sze et al. 2002
1b, 2	**Standard acupuncture with Shixuan & Xiaohai acupoints and experimental acupuncture** may produce greater improvements in motor function than **standard or traditional acupuncture**.	2	Ni et al. 2013; Zhao et al. 2009
2	**Scalp cluster acupuncture combined with CIMT** may not have a difference in efficacy when compared to **body acupuncture with traditional rehabilitation** for improving motor function.	1	Song et al. 2016
1b	**Meridian sinew row needling combined with dermal needling** may produce greater improvements in motor function than **cerebroprotein hydrolysate and piracetam**.	1	Han et al. 2015

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Acupuncture** may produce greater improvements in spasticity than **conventional therapy or sham**.	3	Cui et al. 2014; Zhao et al. 2009; Wayne et al. 2005
2	**Experimental acupuncture** may produce greater improvements in spasticity than **traditional acupuncture**.	1	Zhao et al. 2009
1b	**Meridian sinew row needling combined with dermal needling** may produce greater improvements in spasticity than **cerebroprotein hydrolysate and piracetam**.	1	Han et al. 2015

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **acupuncture** to improve range of motion when compared to **conventional therapy or sham**.	2	Wayne et al. 2009; Naeser et al. 1992

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Acupuncture** may not have a difference in efficacy when compared to **conventional therapy or sham** for improvements on measures of stroke severity.	4	Liu et al. 2016; Zhuangl et al. 2012; Sze et al. 2002; Hu et al. 1993

1b	**Superficial acupuncture** may not have a difference in efficacy when compared to **deep acupuncture** for improvements on measures of stroke severity.	1	Gosman-Hedstrom et al. 1998

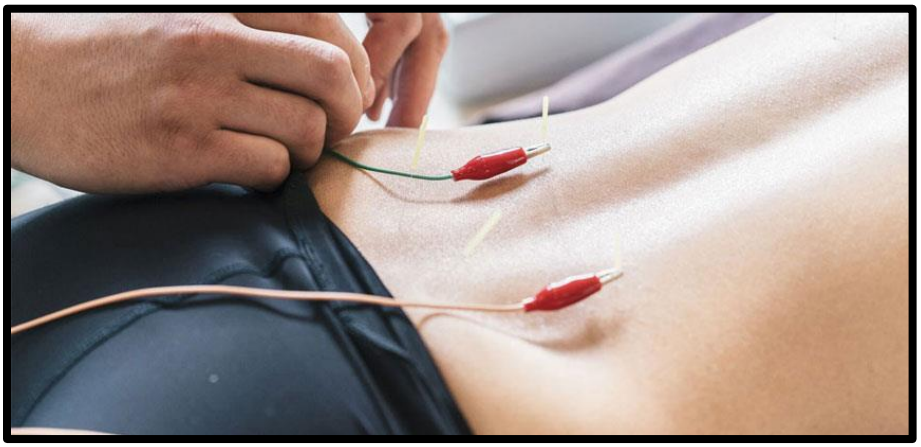
ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Acupuncture** may not have a difference in efficacy when compared to **conventional therapy or sham** for improving performance of activities of daily living.	8	Liu et al. 2016; Bai et al. 2013; Zhuangl et al. 2012; Wayne et al. 2005; Alexander et al. 2004; Sze et al. 2002; Kjendhal et al. 1997; Hu et al.1993
1b	**Acupuncture combined with TENS** may not have a difference in efficacy when compared to **acupuncture with sham stimulation** for improving performance of activities of daily living.	1	Hopwood et al. 2008
1b	**Superficial acupuncture** may not have a difference in efficacy when compared to **deep acupuncture** for improving performance of activities of daily living.	1	Gosman-Hedstom et al. 1998
2	**Experimental acupuncture** may produce greater improvements in performance of activities of daily living than **traditional acupuncture**.	1	Zhao et al. 2009

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Standard acupuncture with Shixuan & Xiaohai acupoints and acupuncture at Tianquan PC2** may produce greater improvements in muscle strength than **standard acupuncture only and acupuncture at Quchi LI11**.	2	Ni et al. 2013; Fragoso and Ferreira, 2012
1b	**Acupuncture combined with TENS** may not have a difference in efficacy when compared to **acupuncture with sham stimulation** for improving muscle strength.	1	Hopwood et al. 2008

Key points

The evidence is mixed regarding acupuncture alone for upper limb rehabilitation following stroke. Acupuncture combined with conventional or other therapy approaches may not be beneficial for upper limb function. Some forms of acupuncture may be more beneficial than others.

Electroacupuncture and transcutaneous electrical acupoint stimulation



Adopted from: https://www.promotionhealthcare.com/electroacupuncture-treatment-pain-injuries/

Electroacupuncture is a variant of acupuncture techniques practiced in traditional Chinese medicine, the difference being that a minute electrical current of similar intensity to that of a bioelectric current produced endogenously in the body is applied to the needles used (Wang et al. 2014). The needle is often placed on meridian points throughout the body (Wang et al. 2014). Similarly, transcutaneous electrical acupoint stimulation (TEAS) stimulates meridian points believed to be associated with a medical condition with electrical impulses given through needles (Zhao et al. 2015). The two techniques have very similar mechanisms of action and their influence on afferent stimulation to the body (Zhao et al. 2015).

11 RCTs were found that evaluated electroacupuncture and transcutaneous electrical acupoint stimulation compared to conventional therapy, sham stimulation, ordinary needling, and strength training (Zhang et al. 2017; Zhao et al. 2015; Au-Yeung et al. 2014; Wang et al. 2014; Wen et al. 2014; Yao et al. 2014; Hsing et al. 2012; Li et al. 2012; Hsieh et al. 2007; Mukherjee et al. 2007; Moon et al. 2003). One RCT looked at electroacupuncture combined with neuronavigation-assisted aspiration compared to neuronavigation-assisted aspiration, electroacupuncture or conventional therapy (Zhang et al. 2017).

The methodological details and results of all 11 RCTs evaluating electroacupuncture and transcutaneous electrical acupoint stimulation for the upper extremity motor rehabilitation are presented in Table 39.

Table 39. RCTs evaluating electroacupuncture and transcutaneous electrical acupoint stimulation interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Zhao et al.(2015) RCT (9) N_{Start}=60 N_{End}=60 TPS=Chronic	E1: Transcutaneous electrical acupoint stimulation (TEAS) (100Hz) E2: Transcutaneous electrical acupoint stimulation (TEAS) (2Hz) C: Sham stimulation Duration: 0, 2, or 100Hz/d, 5d/wk for 4wk	E1 vs C • Modified Ashworth Scale (+exp) • Disability Assessment Scale (-) • Global Assessment Scale (-) Barthel Index (-) E2 vs C • Modified Ashworth Scale (+exp$_2$) • Disability Assessment Scale (-) • Global Assessment Scale (-) • Barthel Index (-) E1 v E2 • Modified Ashworth Scale (+exp) • Disability Assessment Scale (-) • Global Assessment Scale (-) • Barthel Index (-)
Au-Yeung et al. (2014) RCT (6) N_{Start}=73 N_{End}=60 TPS=Acute	E1: Electroacupoint stimulation E2: Sham stimulation C: Conventional therapy (control) Duration: 20Hz/d, 1h/d, 5d/wk for 4wk	E1 vs. C • Hand grip strength (+exp) • Index grip pinch (+exp) E2 vs C & E1 vs E2 • Hand grip strength (-) • Index grip pinch (-) • Action Research Arm Test (-)
Wang et al. (2014) RCT (6) N_{Start}=20 N_{End}=15 TPS=Chronic	E: Electroacupuncture C: No stimulation with no needle manipulation Duration: 50Hz/d, 20min/d, 2d/wk for 6wk	• Elbow joint muscle tone (+exp) • Wrist joint muscle tone (-)
Wen et al. (2014) RCT (7) N_{Start}=300 N_{End}=276 TPS=Acute	E: Electroacupuncture + moxibustion C: Basic therapy Duration: 2 to 15Hz, 5-7d/wk for 4wk	• Fugl-Meyer Assessment (-)
Yao et al. (2014) RCT (5) N_{Start}=68 N_{End}=65 TPS=Chronic	E: Relaxed needling + electroacupuncture C: Ordinary needling Duration: 5Hz, 30min/d, 3d/wk for 8wk	• Fugl-Meyer Assessment (+exp)
Hsing et al. (2012) RCT (7) N_{start}=62 N_{end}=62 TPS=Subacute	E: Scalp electro-acupuncture C: Sham acupuncture Duration: 2 to 100Hz, 30min/d, 2d/wk for 5wk	• Barthel Index (-) • Rankin Scale (-)
Li et al. (2012) RCT (6) N_{start}=120 N_{end}=120 TPS=Acute	E: Electroacupuncture + massage C: Rehabilitation therapy Duration: 25min/d, 5d/wk, 6wk	• Fugl-Meyer Assessment (-) • Modified Rankin Scale (+exp)
Hsieh et al. (2007) RCT (8) N_{start}=63 N_{end}=63 TPS=Subacute	E: Electroacupuncture C: No acupuncture Duration: 20min/d, 2d/wk for 4wk	• Functional Independence Measure (-) • Fugl-Meyer Assessment (+exp)

Mukherjee et al. (2007b) RCT (4) N_{start}=7 N_{end}=7 TPS=Subacute	E: Electroacupuncture + strength training C: Strength training Duration: 2Hz, 40min/d, 2d/wk for 6wk	• Modified Ashworth Scale (+exp)
Moon et al. (2003) RCT (5) N_{start}=35 N_{end}=31 TPS=Subacute	E1: Electroacupuncture E2: Moxibustion C: Routine acupuncture Duration: 50Hz, 30min/d, 3d/wk for 3wk	E1 vs E2/C • Modified Ashworth scale (+exp)
Neuronavigation-assisted aspiration + electroacupuncture		
Zhang et al. (2017) RCT (7) N_{Start}=240 N_{End}=233 TPS=Acute	E1: Neuronavigation-assisted aspiration + electroacupuncture E2: Neuronavigation-assisted aspiration E3: Electroacupuncture C: Conventional therapy Duration: 30min (2x per day) for 8wk	E1 vs E2 • Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp) • Barthel Index (+exp) E1 vs E3 • Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp) • Barthel Index (+exp) E1 vs E4 • Fugl-Meyer Assessment (+exp) • Modified Ashworth Scale (+exp) E3 vs E4 • Fugl-Meyer Assessment ($+exp_3$) • Modified Ashworth Scale ($+exp_3$)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
$+exp_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about electroacupuncture and transcutaneous electrical acupoint stimulation

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **electroacupuncture and transcutaneous electrical acupoint stimulation** to improve motor function when compared to **conventional therapy, sham stimulation, ordinary needling, and strength training**.	6	Zhang et al. 2017; Au-Yeung et al. 2014; Wen et al. 2014; Yao et al. 2014; Li et al. 2012; Hsieh et al. 2007
1b	**Electroacupuncture combined with neuronavigation-assisted aspiration** may produce greater improvements in motor function than **neuronavigation-assisted aspiration, electroacupuncture and conventional therapy on their own**.	1	Zhang et al. 2017

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Electroacupuncture and transcutaneous electrical acupoint stimulation** may produce greater improvements in spasticity than **conventional therapy, sham stimulation, ordinary needling, and strength training**.	5	Zhang et al. 2017; Zhao et al. 2015; Wang et al. 2014; Mukherjee et al. 2007; Moon et al. 2003
1b	**Electroacupuncture combined with neuronavigation-assisted aspiration** may produce greater improvements in spasticity than **neuronavigation-assisted aspiration, electroacupuncture and conventional therapy on their own**.	1	Zhang et al. 2017

STROKE SEVERITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **electroacupuncture and transcutaneous electrical acupoint stimulation** to improve scores on measures of stroke severity when compared to **conventional therapy, sham stimulation, ordinary needling, and strength training**.	2	Hsing et al. 2012; Li et al. 2012

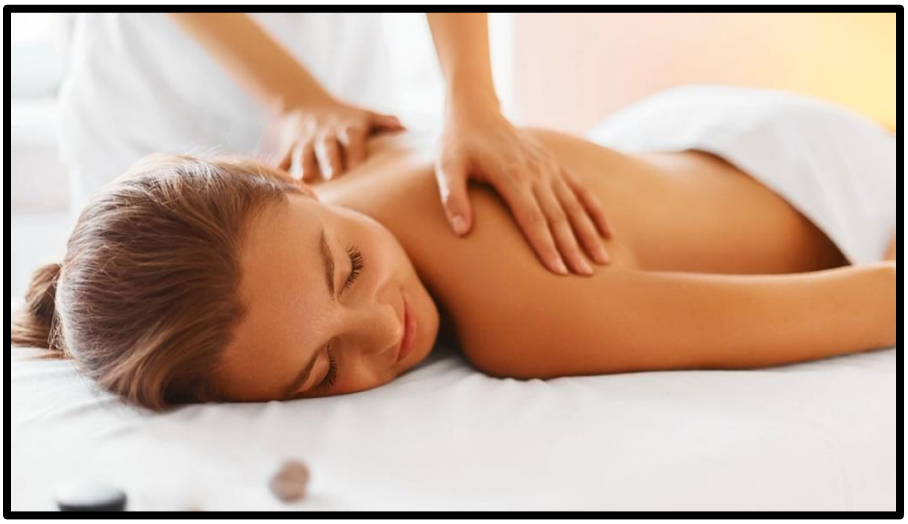
ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Electroacupuncture and transcutaneous electrical acupoint stimulation** may not have a difference in efficacy when compared to **conventional therapy, sham stimulation, ordinary needling, and strength training** for improving performance of activities of daily living.	3	Zhao et al. 2015; Hsieh et al. 2007; Hsing et al. 2012
1b	**Electroacupuncture combined with neuronavigation-assisted aspiration** may produce greater improvements in activities of daily living **neuronavigation-assisted aspiration and electroacupuncture on their own**.	1	Zhang et al. 2017

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
1b	There is conflicting evidence about the effect of **electroacupuncture and transcutaneous electrical acupoint stimulation** to improve muscle strength when compared to **conventional therapy, sham stimulation, ordinary needling, and strength training**.	1	Au-Yeung et al. 2014

Key points

Electroacupuncture with neuronavigation-assisted aspiration may be beneficial for upper limb rehabilitation following stroke, however the evidence is mixed regarding electroacupuncture and transcutaneous electrical acupoint stimulation.

Meridian acupressure and massage therapy



Adopted from: http://physiotherapeutic.ca/servi-physio/111-massage-therapy

Meridian acupressure is a form of treatment whereby finger pressure is applied to meridian points on the body (Yang et al. 2017). There are two types of meridian points: yin and yang (Yang et al. 2017). Yin meridians run from the feet to the torso, and from the torso to the fingertips on the inside of the arms (Cui et al. 2014). On the other hand, yang meridians run from the fingers to the face and from the face to the feet (Cui et al. 2014). Acupressure increases blood (qi) flow to the areas it is applied in (Di et al. 2017).

Massage is the practice of applying structured pressure, tension, motion or vibration — manually or with mechanical aids — to the soft tissues of the body, including: muscles, connective tissue, tendons, ligaments, joints and lymphatic vessels, to achieve a beneficial response (Holland & Pokorny, 2001). As a form of therapy, massage can be applied to parts of the body or successively to the whole body, to heal injury, relieve psychological stress, manage pain, and improve circulation (College of Massage Therapists of Ontario, 2018). The benefits of massage therapy are suggested to be increased blood flow, relief of muscle spasms and release of β-endorphins (Wei et al. 2017). One of the more common forms of massage therapy is the traditional Chinese massage therapy also known as Tui Na (Yang et al. 2017).

The methodological details and results of all 7 RCTs evaluating meridian acupressure and massage therapy for upper extremity motor rehabilitation are presented in Table 40.

Table 40. RCTs evaluating meridian acupressure and massage therapy interventions for upper extremity motor rehabilitation

Authors (Year) Study Design (PEDro Score) Sample Size$_{start}$ Sample Size$_{end}$ Time post stroke category	Interventions Duration: Session length, frequency per week for total number of weeks	Outcome Measures Result (direction of effect)
Di et al. 2017 RCT (5) N_{Start} =150 N_{End} =150 TPS=Subacute	E: Tui Na Therapy C: Conventional therapy Duration: 30min/d, 5d/wk for 4wk	• Modified Ashworth Scale (+exp)
Yang et al. 2017 RCT (8) N_{Start}=90 N_{End}=74 TPS=Subacute	E: Tui Na C: Placebo Tui Na Duration: 20-25min/d, 5d/wk for 4wk	• Modified Ashworth Scale (+exp) • Fugl-Meyer Assessment (-) • Modified Barthel Index (-)
Yang et al. (2017) RCT (8) N_{Start}=90 N_{End}=79 TPS=Subacute	E: Tui Na C: Placebo Therapy Duration: 20-25min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (-) • Modified Barthel Index (-)
Cui et al. (2014) RCT (6) N_{Start}=60 N_{End}=60 TPS=NR	E: Yin Yang manipulation C: Conventional needling manipulation Duration: *Not Specified*	• Elbow spasm (+exp) • Clinical Spasticity Index (+exp)
Thanakiatpinyo et al. (2014) RCT (7) N_{Start}=50 N_{End}=45 TPS=Chronic	E: Thai massage C: Physical therapy Duration: 30min/d, 2d/wk for 6wk	• Modified Ashworth Scale (-) • Barthel Index (-)
Yue et al. (2013) RCT (6) N_{start}=78 N_{end}=72 TPS=Chronic	E: Acupressure C: Routine care Duration: 45min/d, 5d/wk, 4wk	• Barthel Index (+exp) • Fugl-Meyer Assessment (+exp)
Kang et al. (2009) RCT (5) N_{start}=56 N_{end}=56 TPS=Chronic	E: Meridian acupressure C: Standard care Duration: 10min/d, 7d/wk for 2wk	• Grip power (+exp) • Passive range of motion (+exp)

Abbreviations and table notes: C=control group; D=days; E=experimental group; H=hours; Min=minutes; RCT=randomized controlled trial; TPS=time post stroke category (Acute: less than 30 days, Subacute: more than 1 month but less than 6 months, Chronic: over 6 months); Wk=weeks.
+exp indicates a statistically significant between groups difference at α=0.05 in favour of the experimental group
+exp$_2$ indicates a statistically significant between groups difference at α=0.05 in favour of the second experimental group
+con indicates a statistically significant between groups difference at α=0.05 in favour of the control group
- indicates no statistically significant between groups differences at α=0.05

Conclusions about meridian acupressure and massage therapy

MOTOR FUNCTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	There is conflicting evidence about the effect of **meridian acupressure and massage therapy** to improve motor function when compared to **conventional therapy or placebo massage therapy**.	3	Yang et al. 2017; Yang et al. 2017; Yue et al. 2013

MUSCLE STRENGTH			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Meridian acupressure and massage therapy** may produce greater improvements in muscle strength than **conventional therapy**.	1	Kang et al. 2009

RANGE OF MOTION			
LoE	**Conclusion Statement**	**RCTs**	**References**
2	**Meridian acupressure and massage therapy** may produce greater improvements in range of motion than **conventional therapy**.	1	Kang et al. 2009

ACTIVITIES OF DAILY LIVING			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Meridian acupressure and massage therapy** may not have a difference in efficacy when compared to **conventional therapy or placebo massage therapy** for improving performance of activities of daily living.	4	Yang et al. 2017; Yang et al. 2017; Thanakiatpinyo et al. 2014; Yue et al. 2013

SPASTICITY			
LoE	**Conclusion Statement**	**RCTs**	**References**
1a	**Meridian acupressure and massage therapy** may produce greater improvements in spasticity than **conventional therapy or placebo massage therapy**.	4	Di et al. 2017; Yang et al. 2017; Cui et al. 2014; Thanakiatpinyo et al. 2014

Key points

Both meridian acupressure and massage therapy may be beneficial for some aspects of upper limb function following stroke.

References

Abdullah, H. A., Tarry, C., Lambert, C., Barreca, S., & Allen, B. O. (2011). Results of clinicians using a therapeutic robotic system in an inpatient stroke rehabilitation unit. Journal of neuroengineering and rehabilitation, 8(1), 50.

Abdullahi, A. (2016). Upper limb self-efficacy test (UPSET): a measure of confidence in the use of the upper limb after stroke. Advances of Science for Medicine, 1(2), 10-18.

Abo, M., Kakuda, W., Momosaki, R., Harashima, H., Kojima, M., Watanabe, S., ... & Sasanuma, J. (2014). Randomized, multicenter, comparative study of NEURO versus CIMT in poststroke patients with upper limb hemiparesis: the NEURO-VERIFY Study. International Journal of Stroke, 9(5), 607-612.

About Massage Therapy. (2017, May 10). Retrieved April 8, 2019, from https://www.cmto.com/about-the-profession/about-massage-therapy/

Ackerley, S. J., Byblow, W. D., Barber, P. A., MacDonald, H., McIntyre-Robinson, A., & Stinear, C. M. (2016). Primed physical therapy enhances recovery of upper limb function in chronic stroke patients. Neurorehabilitation and neural repair, 30(4), 339-348.

Ada, L., Dorsch, S., & Canning, C. G. (2006). Strengthening interventions increase strength and improve activity after stroke: a systematic review. Australian Journal of Physiotherapy, 52(4), 241-248.

Adie, K., Schofield, C., Berrow, M., Wingham, J., Humfryes, J., Pritchard, C., ... & Allison, R. (2017). Does the use of Nintendo Wii SportsTM improve arm function? Trial of WiiTM in Stroke: A randomized controlled trial and economics analysis. Clinical rehabilitation, 31(2), 173-185.

Agni, P. N., & Kulkarni, V. (2017). Effect of Strength Training, Functional Task Related Training and Combined Strength and Functional Task Related Training On Upper Extremity In Post Stroke Patients. International Journal of Physiotherapy, 4(3), 184-190.

Ahn, S. (2016). Association between daily activities, process skills, and motor skills in community-dwelling patients after left hemiparetic stroke. Journal of physical therapy science, 28(6), 1829-1831.

Alberts, J. L., Butler, A. J., & Wolf, S. L. (2004). The effects of constraint-induced therapy on precision grip: a preliminary study. *Neurorehabilitation and Neural Repair*, *18*(4), 250-258.

Alexander, D. N., Cen, S., Sullivan, K. J., Bhavnani, G., Ma, X., Azen, S. P., & ASAP Study Group. (2004). Effects of acupuncture treatment on poststroke motor recovery and physical function: a pilot study. Neurorehabilitation and neural repair, 18(4), 259-267.

Allen K and Goodman C (2014). Using Electrical Stimulation: A guideline for Allied Health Professionals.

Allgöwer, K., & Hermsdörfer, J. (2017). Fine motor skills predict performance in the Jebsen Taylor Hand Function Test after stroke. Clinical Neurophysiology, 128(10), 1858-1871.

Allman, C., Amadi, U., Winkler, A. M., Wilkins, L., Filippini, N., Kischka, U., ... & Johansen-Berg, H. (2016). Ipsilesional anodal tDCS enhances the functional benefits of rehabilitation in patients after stroke. Science translational medicine, 8(330), 330re1-330re1.

Alon, G., Levitt, A. F., & McCarthy, P. A. (2007). Functional electrical stimulation enhancement of upper extremity functional recovery during stroke rehabilitation: a pilot study. Neurorehabilitation and neural repair, 21(3), 207-215.

Altenmüller, E., Marco-Pallares, J., Münte, T. F., & Schneider, S. (2009). Neural reorganization underlies improvement in stroke-induced motor dysfunction by music-supported therapy. Annals of the New York Academy of Sciences, 1169(1), 395-405.

Altschuler, E. L., Wisdom, S. B., Stone, L., Foster, C., Galasko, D., Llewellyn, D. M. E., & Ramachandran, V. S. (1999). Rehabilitation of hemiparesis after stroke with a mirror. The Lancet, 353(9169), 2035-2036.

Andrade, S. M., Batista, L. M., Nogueira, L. L., Oliveira, E. A. D., de Carvalho, A. G., Lima, S. S., ... & Fernández-Calvo, B. (2017). Constraint-induced movement therapy combined with transcranial direct current stimulation over premotor cortex improves motor function in severe stroke: a pilot randomized controlled trial. Rehabilitation research and practice, 2017.

Ang, K. K., Chua, K. S. G., Phua, K. S., Wang, C., Chin, Z. Y., Kuah, C. W. K., ... & Guan, C. (2015). A randomized controlled trial of EEG-based motor imagery brain-computer interface robotic rehabilitation for stroke. Clinical EEG and neuroscience, 46(4), 310-320.

Ang, K. K., Guan, C., Phua, K. S., Wang, C., Zhao, L., Teo, W. P., ... & Chew, E. (2015). Facilitating effects of transcranial direct current stimulation on motor imagery brain-computer interface with robotic feedback for stroke rehabilitation. Archives of physical medicine and rehabilitation, 96(3), S79-S87.

Arya, K. N., Pandian, S., Kumar, D., & Puri, V. (2015). Task-based mirror therapy augmenting motor recovery in poststroke hemiparesis: a randomized controlled trial. Journal of Stroke and Cerebrovascular Diseases, 24(8), 1738-1748.

Ashford, S., Slade, M., Malaprade, F., & Turner-Stokes, L. (2008). Evaluation of functional outcome measures for the hemiparetic upper limb: a systematic review. Journal of rehabilitation medicine, 40(10), 787-795.

Aşkın, A., Atar, E., Koçyiğit, H., & Tosun, A. (2018). Effects of Kinect-based virtual reality game training on upper extremity motor recovery in chronic stroke. Somatosensory & motor research, 35(1), 25-32.

Aşkın, A., Tosun, A., & Demirdal, Ü. S. (2017). Effects of low-frequency repetitive transcranial magnetic stimulation on upper extremity motor recovery and functional outcomes in chronic stroke patients: A randomized controlled trial. Somatosensory & motor research, 34(2), 102-107.

Au-Yeung, S. S., Wang, J., Chen, Y., & Chua, E. (2014). Transcranial direct current stimulation to primary motor area improves hand dexterity and selective attention in chronic stroke. American journal of physical medicine & rehabilitation, 93(12), 1057-1064.

Awad, A., Shaker, H., Shendy, W., & Fahmy, M. (2015). Effect of shoulder girdle strengthening on trunk alignment in patients with stroke. Journal of physical therapy science, 27(7), 2195-2200.

Bai, Y. L., Li, L., Hu, Y. S., Wu, Y., Xie, P. J., Wang, S. W., ... & Zhu, B. (2013). Prospective, randomized controlled trial of physiotherapy and acupuncture on motor function and daily activities in patients with ischemic stroke. The Journal of Alternative and Complementary Medicine, 19(8), 684-689.

Bakheit, A. M. O., Pittock, S., Moore, A. P., Wurker, M., Otto, S., Erbguth, F., & Coxon, L. (2001). A randomized, double-blind, placebo-controlled study of the efficacy and safety of botulinum toxin type A in upper limb spasticity in patients with stroke. European Journal of Neurology, 8(6), 559-565.

Baldry, P. (2005). The Integration of Acupuncture within Medicine in the UK–the British Medical Acupuncture Society—s 25Th Anniversary. *Acupuncture in Medicine*, *23*(1), 2-12.

Ballester, B. R., Nirme, J., Camacho, I., Duarte, E., Rodríguez, S., Cuxart, A., ... & Verschure, P. F. (2017). Domiciliary VR-based therapy for functional recovery and cortical reorganization: randomized controlled trial in participants at the chronic stage post stroke. JMIR serious games, 5(3).

Bhakta, B. B., Cozens, J. A., Chamberlain, M. A., & Bamford, J. M. (2000). Impact of botulinum toxin type A on disability and carer burden due to arm spasticity after stroke: a randomised double blind placebo controlled trial. Journal of Neurology, Neurosurgery & Psychiatry, 69(2), 217-221.

Barker, R. N., Hayward, K. S., Carson, R. G., Lloyd, D., & Brauer, S. G. (2017). SMART Arm Training With Outcome-Triggered Electrical Stimulation in Subacute Stroke Survivors With Severe Arm Disability: A Randomized Controlled Trial. Neurorehabilitation and neural repair, 31(12), 1005-1016.

Barker, R. N., Brauer, S. G., & Carson, R. G. (2008). Training of reaching in stroke survivors with severe and chronic upper limb paresis using a novel nonrobotic device: a randomized clinical trial. Stroke, 39(6), 1800-1807.

Barreca, S., Gowland, C., Stratford, P., Huijbregts, M., Griffiths, J., Torresin, W., ... & Masters, L. (2004). Development of the Chedoke Arm and Hand Activity Inventory: theoretical constructs, item generation, and selection. Topics in stroke rehabilitation, 11(4), 31-42.

Barry, J. G., Ross, S. A., & Woehrle, J. (2012). Therapy incorporating a dynamic wrist-hand orthosis versus manual assistance in chronic stroke: A pilot study. Journal of Neurologic Physical Therapy, 36(1), 17-24.

Barzel, A., Ketels, G., Stark, A., Tetzlaff, B., Daubmann, A., Wegscheider, K., ... & Scherer, M. (2015). Home-based constraint-induced movement therapy for patients with upper limb dysfunction after stroke (HOMECIMT): a cluster-randomised, controlled trial. The Lancet Neurology, 14(9), 893-902.

Basaran, A., Emre, U., Ikbal Karadavut, K., Balbaloglu, O., & Bulmus, N. (2012). Hand splinting for poststroke spasticity: a randomized controlled trial. Topics in stroke rehabilitation, 19(4), 329-337.

Basmajian, J. V., Gowland, C. A., Finlayson, M. A., Hall, A. L., Swanson, L. R., Stratford, P. W., ... & Brandstater, M. E. (1987). Stroke treatment: comparison of integrated behavioral-physical therapy vs traditional physical therapy programs. Archives of Physical Medicine and Rehabilitation, 68(5 Pt 1), 267-272.

Batool, S., Soomro, N., Amjad, F., & Fauz, R. (2015). To compare the effectiveness of constraint induced movement therapy versus motor relearning programme to improve motor function of hemiplegic upper extremity after stroke. *Pakistan journal of medical sciences*, *31*(5), 1167.

Baygutalp, F., & ŞENEL, K. (2014). Effect of Neuromuscular Electrical Stimulation In Hemiplegic Upper Extremity Rehabilitation. Turkish Journal of Geriatrics/Türk Geriatri Dergisi, 17(1).

Beebe, J. A., & Lang, C. E. (2009). Active range of motion predicts upper extremity function 3 months after stroke. Stroke, 40(5), 1772-1779.

Beebe, J. A., & Lang, C. E. (2009). Relationships and responsiveness of six upper extremity function tests during the first 6 months of recovery after stroke. Journal of neurologic physical therapy: JNPT, 33(2), 96.

Bell, K. R., & Williams, F. (2003). Use of botulinum toxin type A and type B for spasticity in upper and lower limbs. Physical medicine and rehabilitation clinics of North America, 14(4), 821-835.

Benvenuti, F., Stuart, M., Cappena, V., Gabella, S., Corsi, S., Taviani, A., ... & Weinrich, M. (2014). Community-based exercise for upper limb paresis: a controlled trial with telerehabilitation. Neurorehabilitation and neural repair, 28(7), 611-620.

Bertrand, A. M., Fournier, K., Brasey, M. G. W., Kaiser, M. L., Frischknecht, R., & Diserens, K. (2015). Reliability of maximal grip strength measurements and grip strength recovery following a stroke. Journal of Hand Therapy, 28(4), 356-363.

Bhatt, E., Nagpal, A., Greer, K. H., Grunewald, T. K., Steele, J. L., Wiemiller, J. W., ... & Carey, J. R. (2007). Effect of finger tracking combined with electrical stimulation on brain reorganization and hand function in subjects with stroke. Experimental brain research, 182(4), 435-447.

Boake, C., Noser, E. A., Ro, T., Baraniuk, S., Gaber, M., Johnson, R., ... & Moye, L. A. (2007). Constraint-induced movement therapy during early stroke rehabilitation. Neurorehabilitation and neural repair, 21(1), 14-24.

Boccuni, L., Meyer, S., Kessner, S. S., De Bruyn, N., Essers, B., Cheng, B., ... & Marinelli, L. (2018). Is There Full or Proportional Somatosensory Recovery in the Upper Limb After Stroke? Investigating Behavioral Outcome and Neural Correlates. Neurorehabilitation and neural repair, 32(8), 691-700.

Boggio, P. S., Nunes, A., Rigonatti, S. P., Nitsche, M. A., Pascual-Leone, A., & Fregni, F. (2007). Repeated sessions of noninvasive brain DC stimulation is associated with motor

function improvement in stroke patients. Restorative neurology and neuroscience, 25(2), 123-129.

Borges, L. R., Fernandes, A. B., Melo, L. P., Guerra, R. O., & Campos, T. F. (2018). Action observation for upper limb rehabilitation after stroke. Cochrane Database of Systematic Reviews, 21(10), 234-244.

Bouffioulx, É., Arnould, C., Vandervelde, L., & Thonnard, J. L. (2010). Changes in satisfaction with activities and participation between acute, post-acute and chronic stroke phases: A responsiveness study of the SATIS-stroke questionnaire. Journal of rehabilitation medicine, 42(10), 944-948.

Bouffioulx, É., Arnould, C., & Thonnard, J. L. (2008). SATIS-Stroke: a satisfaction measure of activities and participation in the actual environment experienced by patients with chronic stroke. Journal of rehabilitation medicine, 40(10), 836-843.

Bovend'Eerdt, T. J., Dawes, H., Sackley, C., Izadi, H., & Wade, D. T. (2010). An integrated motor imagery program to improve functional task performance in neurorehabilitation: a single-blind randomized controlled trial. Archives of physical medicine and rehabilitation, 91(6), 939-946.

Bovend'Eerdt, T. J., Dawes, H., Johansen-Berg, H., & Wade, D. T. (2004). Evaluation of the Modified Jebsen Test of Hand Function and the University of Maryland Arm Questionnaire for Stroke. Clinical rehabilitation, 18(2), 195-202.

Bowman, B. R., Baker, L. L., & Waters, R. L. (1979). Positional feedback and electrical stimulation: an automated treatment for the hemiplegic wrist. Archives of Physical Medicine and Rehabilitation, 60(11), 497-502.

Boyaci, A., Topuz, O., Alkan, H., Ozgen, M., Sarsan, A., Yildiz, N., & Ardic, F. (2013). Comparison of the effectiveness of active and passive neuromuscular electrical stimulation of hemiplegic upper extremities: a randomized, controlled trial. International Journal of Rehabilitation Research, 36(4), 315-322.

Boyd, L. A., Vidoni, E. D., & Wessel, B. D. (2010). Motor learning after stroke: is skill acquisition a prerequisite for contralesional neuroplastic change?. Neuroscience letters, 482(1), 21-25.

Bang, D. H., Shin, W. S., & Choi, S. J. (2015). The effects of modified constraint-induced movement therapy combined with trunk restraint in subacute stroke: a double-blinded randomized controlled trial. Clinical rehabilitation, 29(6), 561-569.

Bartolo, M., De Nunzio, A. M., Sebastiano, F., Spicciato, F., Tortola, P., Nilsson, J., & Pierelli, F. (2014). Arm weight support training improves functional motor outcome and movement smoothness after stroke. Functional neurology, 29(1), 15.

Blackburn, M., Van Vliet, P., & Mockett, S. P. (2002). Reliability of measurements obtained with the modified Ashworth scale in the lower extremities of people with stroke. Physical therapy, 82(1), 25-34.

Brashear, A., Gordon, M. F., Elovic, E., Kassicieh, V. D., Marciniak, C., Do, M., ... & Turkel, C. (2002). Intramuscular injection of botulinum toxin for the treatment of wrist and finger spasticity after a stroke. New England Journal of Medicine, 347(6), 395-400.

Brashear, A., McAfee, A. L., Kuhn, E. R., & Fyffe, J. (2004). Botulinum toxin type B in upper-limb poststroke spasticity: a double-blind, placebo-controlled trial. *Archives of physical medicine and rehabilitation*, *85*(5), 705-709.

Brashear, A., Zafonte, R., Corcoran, M., Galvez-Jimenez, N., Gracies, J. M., Gordon, M. F., ... & Lee, C. H. (2002). Inter-and intrarater reliability of the Ashworth Scale and the Disability Assessment Scale in patients with upper-limb poststroke spasticity. Archives of physical medicine and rehabilitation, 83(10), 1349-1354.

Brkic, L., Shaw, L., van Wijck, F., Francis, R., Price, C., Forster, A., ... & Rodgers, H. (2016). Repetitive arm functional tasks after stroke (RAFTAS): a pilot randomised controlled trial. Pilot and Feasibility Studies, 2(1), 50.

Brogårdh, C., Vestling, M., & Sjölund, B. H. (2009). Shortened constraint-induced movement therapy in subacute stroke–no effect of using a restraint: a randomized controlled study with independent observers. Journal of rehabilitation medicine, 41(4), 231-236.

Brogårdh, C., Persson, A. L., & Sjölund, B. H. (2007). Intra-and inter-rater reliability of the Sollerman hand function test in patients with chronic stroke. Disability and rehabilitation, 29(2), 145-154.

Brogårdh, C., & Sjölund, B. H. (2006). Constraint-induced movement therapy in patients with stroke: a pilot study on effects of small group training and of extended mitt use. Clinical rehabilitation, 20(3), 218-227.

Brokaw, E. B., Nichols, D., Holley, R. J., & Lum, P. S. (2014). Robotic therapy provides a stimulus for upper limb motor recovery after stroke that is complementary to and distinct from conventional therapy. Neurorehabilitation and neural repair, 28(4), 367-376.

Brown, J. A., Lutsep, H. L., Weinand, M., & Cramer, S. C. (2006). Motor cortex stimulation for the enhancement of recovery from stroke: a prospective, multicenter safety study. Neurosurgery, 58(3), 464-473.

Brunner, I., Skouen, J. S., Hofstad, H., Aßmus, J., Becker, F., Sanders, A. M., ... & Verheyden, G. (2017). Virtual reality training for upper extremity in subacute stroke (VIRTUES): a multicenter RCT. *Neurology*, *89*(24), 2413-2421.

Brunner, I. C., Skouen, J. S., & Strand, L. I. (2012). Is modified constraint-induced movement therapy more effective than bimanual training in improving arm motor function in the subacute phase post stroke? A randomized controlled trial. Clin.Rehabil., 26(12), 1078-1086.

Brunnstrom, S. (1970). Movement therapy in hemiplegia. A neurophysiological approach, 113-122.

Burgar, C. G., Lum, P. S., Scremin, A. E., Garber, S. L., Van der Loos, H. M., Kenney, D., & Shor, P. (2011). Robot-assisted upper-limb therapy in acute rehabilitation setting following stroke: Department of Veterans Affairs multisite clinical trial. Journal of Rehabilitation Research & Development, 48(4), 445-459.

Burgar, C. G., Lum, P. S., Shor, P. C., & Van der Loos, H. M. (2000). Development of robots for rehabilitation therapy: the Palo Alto VA/Stanford experience. Journal of rehabilitation research and development, 37(6), 663-674.

Bütefisch, C., Hummelsheim, H., Denzler, P., & Mauritz, K. H. (1995). Repetitive training of isolated movements improves the outcome of motor rehabilitation of the centrally paretic hand. Journal of the neurological sciences, 130(1), 59-68.

Byl, N. N., Abrams, G. M., Pitsch, E., Fedulow, I., Kim, H., Simkins, M., . . . Rosen, J. (2013). Chronic stroke survivors achieve comparable outcomes following virtual task specific repetitive training guided by a wearable robotic orthosis (UL-EX07) and actual task specific repetitive training guided by a physical therapist. Journal of Hand Therapy, 26(4), 343-352.

Calabrò, R. S., Naro, A., Russo, M., Milardi, D., Leo, A., Filoni, S., ... & Bramanti, P. (2017). Is two better than one? Muscle vibration plus robotic rehabilitation to improve upper limb spasticity and function: A pilot randomized controlled trial. PloS one, 12(10), e0185936.

Caliandro, P., Celletti, C., Padua, L., Minciotti, I., Russo, G., Granata, G., ... & Camerota, F. (2012). Focal muscle vibration in the treatment of upper limb spasticity: a pilot randomized controlled trial in patients with chronic stroke. Archives of physical medicine and rehabilitation, 93(9), 1656-1661.

Cambier, D. C., De Corte, E., Danneels, L. A., & Witvrouw, E. E. (2003). Treating sensory impairments in the post-stroke upper limb with intermittent pneumatic compression. Results of a preliminary trial. Clinical rehabilitation, 17(1), 14-20.

Capone, F., Miccinilli, S., Pellegrino, G., Zollo, L., Simonetti, D., Bressi, F., ... & Pepe, A. (2017). Transcutaneous vagus nerve stimulation combined with robotic rehabilitation improves upper limb function after stroke. Neural plasticity, 2017.

Carda, S., Biasiucci, A., Maesani, A., Ionta, S., Moncharmont, J., Clarke, S., ... & Millán, J. D. R. (2017). Electrically assisted movement therapy in chronic stroke patients with severe upper limb paresis: a pilot, single-blind, randomized crossover study. Archives of physical medicine and rehabilitation, 98(8), 1628-1635.

Cassidy, J. M., Chu, H., Anderson, D. C., Krach, L. E., Snow, L., Kimberley, T. J., & Carey, J. R. (2015). A comparison of primed low-frequency repetitive transcranial magnetic stimulation treatments in chronic stroke. Brain stimulation, 8(6), 1074-1084.

Cauraugh, J. H., & Kim, S. B. (2003). Stroke motor recovery: active neuromuscular stimulation and repetitive practice schedules. J.Neurol.Neurosurg.Psychiatry, 74(11), 1562-1566.

Cauraugh, J., Light, K., Kim, S., Thigpen, M., & Behrman, A. (2000). Chronic motor dysfunction after stroke: recovering wrist and finger extension by electromyography-triggered neuromuscular stimulation. Stroke, 31(6), 1360-1364.

Celletti, C., Fara, M. A., Filippi, G. M., La Torre, G., Tozzi, R., Vanacore, N., & Camerota, F. (2017). Focal Muscle Vibration and Physical Exercise in Postmastectomy Recovery: An Explorative Study. BioMed research international, 2017.

Celnik, P., Hummel, F., Harris-Love, M., Wolk, R., & Cohen, L. G. (2007). Somatosensory stimulation enhances the effects of training functional hand tasks in patients with chronic stroke. Archives of physical medicine and rehabilitation, 88(11), 1369-1376.

Cha, H. K., Ji, S. G., Kim, M. K., & Chang, J. S. (2014). Effect of transcranial direct current stimulation of function in patients with stroke. Journal of physical therapy science, 26(3), 363-365.

Chang, W. H., Park, C. H., Kim, D. Y., Shin, Y. I., Ko, M. H., Lee, A., ... & Kim, Y. H. (2016). Cerebrolysin combined with rehabilitation promotes motor recovery in patients with severe motor impairment after stroke. BMC neurology, 16(1), 31.

Chae, J., Harley, M. Y., Hisel, T. Z., Corrigan, C. M., Demchak, J. A., Wong, Y. T., & Fang, Z. P. (2009). Intramuscular electrical stimulation for upper limb recovery in chronic hemiparesis: an exploratory randomized clinical trial. Neurorehabilitation and neural repair, 23(6), 569-578.

Chae, J., Bethoux, F., Bohinc, T., Dobos, L., Davis, T., & Friedl, A. (1998). Neuromuscular stimulation for upper extremity motor and functional recovery in acute hemiplegia. Stroke, 29(5), 975-979

Chan, M. K. L., Tong, R. K. Y., & Chung, K. Y. K. (2009). Bilateral upper limb training with functional electric stimulation in patients with chronic stroke. Neurorehabilitation and Neural Repair, 23(4), 357-365.

Chang, W. H., Kim, Y. H., Bang, O. Y., Kim, S. T., Park, Y. H., & Lee, P. K. (2010). Long-term effects of rTMS on motor recovery in patients after subacute stroke. Journal of rehabilitation medicine, 42(8), 758-764.

Chemerinski, E., Robinson, R. G., & Kosier, J. T. (2001). Improved recovery in activities of daily living associated with remission of poststroke depression. Stroke, 32(1), 113-117.

Chen, J. C., Liang, C. C., & Shaw, F. Z. (2005). Facilitation of sensory and motor recovery by thermal intervention for the hemiplegic upper limb in acute stroke patients: a single-blind randomized clinical trial. Stroke, 36(12), 2665-2669.

Chen, L., Fang, J., Ma, R., Gu, X., Chen, L., Li, J., & Xu, S. (2016). Additional effects of acupuncture on early comprehensive rehabilitation in patients with mild to moderate acute ischemic stroke: a multicenter randomized controlled trial. *BMC complementary and alternative medicine*, *16*(1), 226.

Childers, M. K., Brashear, A., Jozefczyk, P., Reding, M., Alexander, D., Good, D., ... & Molloy, P. T. (2004). Dose-dependent response to intramuscular botulinum toxin type A for upper-limb spasticity in patients after a stroke. Archives of Physical Medicine and Rehabilitation, 85(7), 1063-1069.

Cho, H. S., & Cha, H. G. (2015). Effect of mirror therapy with tDCS on functional recovery of the upper extremity of stroke patients. Journal of physical therapy science, 27(4), 1045-1047.

Choi, J. B., & Ma, S. R. (2017). The effect of resting hand splint on hand pain and edema among patients with stroke. Journal of Ecophysiology and Occupational Health, 16(1-2), 37-41.

Choi, J. B., Yang, J. E., & Song, B. K. (2017). The effect of different types of resting hand splints on spasticity and hand function among patients with stroke. Journal of Ecophysiology and Occupational Health, 16(1-2), 42-51.

Choi, J. H., Han, E. Y., Kim, B. R., Kim, S. M., Im, S. H., Lee, S. Y., & Hyun, C. W. (2014). Effectiveness of commercial gaming-based virtual reality movement therapy on functional recovery of upper extremity in subacute stroke patients. Annals of rehabilitation medicine, 38(4), 485.

Choi, Y. H., Ku, J., Lim, H., Kim, Y. H., & Paik, N. J. (2016). Mobile game-based virtual reality rehabilitation program for upper limb dysfunction after ischemic stroke. Restorative neurology and neuroscience, 34(3), 455-463.

Chollet, F., Tardy, J., Albucher, J. F., Thalamas, C., Berard, E., Lamy, C., ... & Guillon, B. (2011). Fluoxetine for motor recovery after acute ischaemic stroke (FLAME): a randomised placebo-controlled trial. The Lancet Neurology, 10(2), 123-130.

Chuang, L. L., Chen, Y. L., Chen, C. C., Li, Y. C., Wong, A. M. K., Hsu, A. L., & Chang, Y. J. (2017). Effect of EMG-triggered neuromuscular electrical stimulation with bilateral arm training on hemiplegic shoulder pain and arm function after stroke: a randomized controlled trial. Journal of neuroengineering and rehabilitation, 14(1), 122.

Chuang, I. C., Lin, K. C., Wu, C. Y., Hsieh, Y. W., Liu, C. T., & Chen, C. L. (2017). Using Rasch Analysis to Validate the Motor Activity Log and the Lower Functioning Motor Activity Log in Patients With Stroke. Physical therapy, 97(10), 1030-1040.

Cipriani, A., Purgato, M., Furukawa, T. A., Trespidi, C., Imperadore, G., Signoretti, A., ... & Barbui, C. (2012). Citalopram versus other anti-depressive agents for depression. Cochrane Database of Systematic Reviews, (7).

Cirstea, M. C., Mitnitski, A. B., Feldman, A. G., & Levin, M. F. (2003). Interjoint coordination dynamics during reaching in stroke. Experimental Brain Research, 151(3), 289-300.

Classen, J., Liepert, J., Wise, S. P., Hallett, M., & Cohen, L. G. (1998). Rapid plasticity of human cortical movement representation induced by practice. Journal of neurophysiology, 79(2), 1117-1123.

Colomer, C., Noe, E., & Llorens Rodríguez, R. (2016). Mirror therapy in chronic stroke survivors with severely impaired upper limb function: a randomized controlled trial. European journal of physical and rehabilitation medicine, 52(3), 271-278.

Conforto, A. B., Anjos, S. M., Saposnik, G., Mello, E. A., Nagaya, E. M., Santos, W., ... & Cohen, L. G. (2012). Transcranial magnetic stimulation in mild to severe hemiparesis early after stroke: a proof of principle and novel approach to improve motor function. Journal of neurology, 259(7), 1399-1405.

Coroian, F., Jourdan, C., Bakhti, K., Palayer, C., Jaussent, A., Picot, M. C., ... & Laffont, I. (2018). Upper limb isokinetic strengthening versus passive mobilization in patients with chronic stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 99(2), 321-328.

Conforto, A. B., Kaelin-Lang, A., & Cohen, L. G. (2002). Increase in hand muscle strength of stroke patients after somatosensory stimulation. Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society, 51(1), 122-125.

Conroy, S. S., Whitall, J., Dipietro, L., Jones-Lush, L. M., Zhan, M., Finley, M. A., ... & Bever, C. T. (2011). Effect of gravity on robot-assisted motor training after chronic stroke: a randomized trial. Archives of physical medicine and rehabilitation, 92(11), 1754-1761.

Costantino, C., Galuppo, L., & Romiti, D. (2017). Short-term effect of local muscle vibration treatment versus sham therapy on upper limb in chronic post-stroke patients: a randomized controlled trial. Eur J Phys Rehabil Med, 53(1), 32-40.

Coote, S., Murphy, B., Harwin, W., & Stokes, E. (2008). The effect of the GENTLE/s robot-mediated therapy system on arm function after stroke. Clinical rehabilitation, 22(5), 395-405.

Corti, M., McGuirk, T. E., Wu, S. S., & Patten, C. (2012). Differential effects of power training versus functional task practice on compensation and restoration of arm function after stroke. Neurorehabilitation and neural repair, 26(7), 842-854.

Cotoi, A., Mirkowski, M., Iruthayarajah, J., Anderson, R., & Teasell, R. (2019). The effect of theta-burst stimulation on unilateral spatial neglect following stroke: a systematic review. Clinical rehabilitation, 33(2), 183-194.

Cowles, T., Clark, A., Mares, K., Peryer, G., Stuck, R., & Pomeroy, V. (2013). Observation-to-imitate plus practice could add little to physical therapy benefits within 31 days of stroke: translational randomized controlled trial. Neurorehabilitation and Neural Repair, 27(2), 173-182.

Craig, J. C. (1999). Grating orientation as a measure of tactile spatial acuity. Somatosensory & motor research, 16(3), 197-206.

Cristina, L. M., Matei, D., Ignat, B., & Popescu, C. D. (2015). Mirror therapy enhances upper extremity motor recovery in stroke patients. Acta neurologica belgica, 115(4), 597-603.

Crosbie, J. H., Lennon, S., McGoldrick, M. C., McNeill, M. D. J., & McDonough, S. M. (2012). Virtual reality in the rehabilitation of the arm after hemiplegic stroke: a randomized controlled pilot study. Clinical Rehabilitation, 26(9), 798-806.

Cunningham, D. A., Varnerin, N., Machado, A., Bonnett, C., Janini, D., Roelle, S., ... & Plow, E. B. (2015). Stimulation targeting higher motor areas in stroke rehabilitation: a proof-of-concept, randomized, double-blinded placebo-controlled study of effectiveness and underlying mechanisms. Restorative neurology and neuroscience, 33(6), 911-926.

Cui, H. F., Gao, G. Q., Wang, Y. L., Yu, X. H., Guo, L., & Ren, S. (2014). Therapeutic efficacy analysis of balancing yin-yang manipulation for post-stroke upper limb spasticity. Journal of Acupuncture and Tuina Science, 12(6), 369-374.

D'Agata, F., Peila, E., Cicerale, A., Caglio, M. M., Caroppo, P., Vighetti, S., ... & Molo, M. T. (2016). Cognitive and neurophysiological effects of non-invasive brain stimulation in stroke patients after motor rehabilitation. Frontiers in behavioral neuroscience, 10, 135.

Dahl, A. E., Askim, T., Stock, R., Langørgen, E., Lydersen, S., & Indredavik, B. (2008). Short- and long-term outcome of constraint-induced movement therapy after stroke: a randomized controlled feasibility trial. Clinical Rehabilitation, 22(5), 436-447.

Dam, M., Tonin, P., De Boni, A., Pizzolato, G., Casson, S., Ermani, M., ... & Battistin, L. (1996). Effects of fluoxetine and maprotiline on functional recovery in poststroke hemiplegic patients undergoing rehabilitation therapy. Stroke, 27(7), 1211-1214.

Dawson, J., Pierce, D., Dixit, A., Kimberley, T. J., Robertson, M., Tarver, B., ... & Rennaker, R. L. (2016). Safety, feasibility, and efficacy of vagus nerve stimulation paired with upper-limb rehabilitation after ischemic stroke. Stroke, 47(1), 143-150.

das Nair, R. D., Moreton, B. J., & Lincoln, N. B. (2011). Rasch analysis of the Nottingham extended activities of daily living scale. Journal of rehabilitation medicine, 43(10), 944-950.

da Silva, L. C. T. (2017). Nine-hole peg test for evaluation of hand function: The advantages and shortcomings. Neurology India, 65(5), 1033.

da Silva, P. B., Antunes, F. N., Graef, P., Cechetti, F., & de Souza Pagnussat, A. (2015). Strength training associated with task-oriented training to enhance upper-limb motor function in elderly patients with mild impairment after stroke: a randomized controlled trial. American journal of physical medicine & rehabilitation, 94(1), 11-19.

da Silva Ribeiro, N. M., Ferraz, D. D., Pedreira, É., Pinheiro, Í., da Silva Pinto, A. C., Neto, M. G., ... & Masruha, M. R. (2015). Virtual rehabilitation via Nintendo Wii® and conventional physical therapy effectively treat post-stroke hemiparetic patients. Topics in stroke rehabilitation, 22(4), 299-305.

Daunoraviciene, K., Adomaviciene, A., Grigonyte, A., Griškevičius, J., & Juocevicius, A. (2018). Effects of robot-assisted training on upper limb functional recovery during the rehabilitation of poststroke patients. Technology and Health Care, (Preprint), 1-10.

Dehem, S., Gilliaux, M., Lejeune, T., Delaunois, E., Mbonda, P., Vandermeeren, Y., ... & Stoquart, G. (2018). Effectiveness of a single session of dual-transcranial direct current stimulation in combination with upper limb robotic-assisted rehabilitation in chronic stroke patients: a randomized, double-blind, cross-over study. International Journal of Rehabilitation Research, 41(2), 138-145.

de Jong, L. D., Dijkstra, P. U., Gerritsen, J., Geurts, A. C., & Postema, K. (2013). Combined arm stretch positioning and neuromuscular electrical stimulation during rehabilitation does not improve range of motion, shoulder pain or function in patients after stroke: a randomised trial. Journal of physiotherapy, 59(4), 245-254.

De Kroon, J. R., & IJzerman, M. J. (2008). Electrical stimulation of the upper extremity in stroke: cyclic versus EMG-triggered stimulation. Clinical rehabilitation, 22(8), 690-697.

Del Felice, A., Daloli, V., Masiero, S., & Manganotti, P. (2016). Contralesional cathodal versus dual transcranial direct current stimulation for decreasing upper limb spasticity in chronic stroke individuals: a clinical and neurophysiological study. Journal of Stroke and Cerebrovascular Diseases, 25(12), 2932-2941.

Dell'Uomo, Daniela, Giovanni Morone, Antonio Centrella, Stefano Paolucci, Carlo Caltagirone, Maria Grazia Grasso, Marco Traballesi, and Marco Iosa. "Effects of scapulohumeral rehabilitation protocol on trunk control recovery in patients with subacute stroke: A pilot randomized controlled trial." NeuroRehabilitation 40, no. 3 (2017): 337-343.

Demanboro, A., Sterr, A., Anjos, S. M. D., & Conforto, A. B. (2018). A Brazilian-Portuguese version of the Kinesthetic and Visual Motor Imagery Questionnaire. Arquivos de neuro-psiquiatria, 76(1), 26-31.

Demir, Y., Alaca, R., Yazicioğlu, K., Yaşar, E., & Tan, A. K. (2018). The Effect of Functional Electrical Stimulation on Stroke Recovery: A Randomized Controlled Trial. Journal of Physical Medicine & Rehabilitation Sciences/Fiziksel Tup ve Rehabilitasyon Bilimleri Dergisi, 21(2).

Desrosiers, J., Bourbonnais, D., Corriveau, H., Gosselin, S., & Bravo, G. (2005). Effectiveness of unilateral and symmetrical bilateral task training for arm during the subacute phase after stroke: a randomized controlled trial. Clin.Rehabil., 19(6), 581-593.

Devier, D., Harnar, J., Lopez, L., Brashear, A., & Graham, G. (2017). Rehabilitation plus OnabotulinumtoxinA Improves Motor Function over OnabotulinumtoxinA Alone in Post-Stroke Upper Limb Spasticity: A Single-Blind, Randomized Trial. Toxins, 9(7), 216.

Dias, P., Silva, R., Amorim, P., Laíns, J., Roque, E., Serôdio, I., ... & Potel, M. (2019). Using Virtual Reality to Increase Motivation in Poststroke Rehabilitation. IEEE Computer Graphics and Applications, 39(1), 64-70.

Dickstein, R., Hocherman, S., Pillar, T., & Shaham, R. (1986). Stroke rehabilitation: three exercise therapy approaches. Physical Therapy, 66(8), 1233-1238.

Di, H. Y., Han, S. K., Du, X. L., Li, W. W., & Jia, J. (2017). Applying tuina to exterior-interiorly connected meridians for post-stroke upper limb spasticity. Journal of Acupuncture and Tuina Science, 15(1), 27-30.

Di Lazzaro, V., Capone, F., Di Pino, G., Pellegrino, G., Florio, L., Zollo, L., ... & Miccinilli, S. (2016). Combining robotic training and non-invasive brain stimulation in severe upper limb-impaired chronic stroke patients. Frontiers in neuroscience, 10, 88.

Di Lazzaro, V., Rothwell, J. C., Talelli, P., Capone, F., Ranieri, F., Wallace, A. C., ... & Dileone, M. (2013). Inhibitory theta burst stimulation of affected hemisphere in chronic stroke: a proof of principle, sham-controlled study. Neuroscience letters, 553, 148-152.

Dionisio, A., Duarte, I. C., Patricio, M., & Castelo-Branco, M. (2018). The use of repetitive transcranial magnetic stimulation for stroke rehabilitation: a systematic review. Journal of Stroke and Cerebrovascular Diseases, 27(1), 1-31.

Dispa, D., Lejeune, T., & Thonnard, J.-L. (2013). The effect of repetitive rhythmic precision grip taskoriented rehabilitation in chronic stroke patients: a pilot study. International Journal of Rehabilitation Research, 36(1), 81.

Dodakian, L., McKenzie, A. L., Le, V., See, J., Pearson-Fuhrhop, K., Burke Quinlan, E., ... & Reinkensmeyer, D. J. (2017). A home-based telerehabilitation program for patients with stroke. Neurorehabilitation and neural repair, 31(10-11), 923-933.

Doğan, A., Demirtaş, R., & Özgirgin, N. (2013). Intraarticular hydraulic distension with steroids in the management of hemiplegic shoulder. Turkish Journal of Medical Sciences, 43(2), 304-310.

Dohle, C., Püllen, J., Nakaten, A., Küst, J., Rietz, C., & Karbe, H. (2009). Mirror therapy promotes recovery from severe hemiparesis: a randomized controlled trial. Neurorehabilitation and neural repair, 23(3), 209-217.

Dong, Y., Steins, D., Sun, S., Li, F., Amor, J. D., James, C. J., ... & Wade, D. T. (2018). Does feedback on daily activity level from a Smart watch during inpatient stroke rehabilitation increase physical activity levels? Study protocol for a randomized controlled trial. Trials, 19(1), 177.

Dorsch, S., Ada, L., & Canning, C. G. (2014). EMG-triggered electrical stimulation is a feasible intervention to apply to multiple arm muscles in people early after stroke, but does not improve strength and activity more than usual therapy: a randomized feasibility trial. Clinical rehabilitation, 28(5), 482-490.

dos Santos-Fontes, R. L., Ferreiro de Andrade, K. N., Sterr, A., & Conforto, A. B. (2013). Home-based nerve stimulation to enhance effects of motor training in patients in the chronic phase after stroke: a proof-of-principle study. Neurorehabilitation and Neural Repair, 27(6), 483-490.

Doucet, B. M., & Griffin, L. (2013). High-versus low-frequency stimulation effects on fine motor control in chronic hemiplegia: a pilot study. Topics in stroke rehabilitation, 20(4), 299-307.

Doussoulin, A., Arancibia, M., Saiz, J., Silva, A., Luengo, M., & Salazar, A. P. (2017). Recovering functional independence after a stroke through Modified Constraint-Induced Therapy. NeuroRehabilitation, 40(2), 243-249.

Dromerick, A. W., Lang, C. E., Birkenmeier, R. L., Wagner, J. M., Miller, J. P., Videen, T. O., ... & Edwards, D. F. (2009). Very early constraint-induced movement during stroke rehabilitation (VECTORS): a single-center RCT. Neurology, 73(3), 195-201.

Dromerick, A. W., Edwards, D. F., & Hahn, M. (2000). Does the application of constraint-induced movement therapy during acute rehabilitation reduce arm impairment after ischemic stroke?. Stroke, 31(12), 2984-2988.

Duff, M., Chen, Y., Cheng, L., Liu, S. M., Blake, P., Wolf, S. L., & Rikakis, T. (2013). Adaptive mixed reality rehabilitation improves quality of reaching movements more than traditional reaching therapy following stroke. *Neurorehabilitation and neural repair*, *27*(4), 306-315.

Du, J., L. Tian, W. Liu, J. Hu, G. Xu, M. Ma, X. Fan et al. "Effects of repetitive transcranial magnetic stimulation on motor recovery and motor cortex excitability in patients with stroke: a randomized controlled trial." European journal of neurology 23, no. 11 (2016): 1666-1672.

El-Helow, M. R., Zamzam, M. L., Fathalla, M. M., El-Badawy, M. A., El Nahhas, N., El-Nabil, L. M., ... & Von Wild, K. (2015). Efficacy of modified constraint-induced movement therapy in acute stroke. *Eur J Phys Rehabil Med*, *51*(4), 371-9.

Ellis, M. D., Carmona, C., Drogos, J., & Dewald, J. (2018). Progressive abduction loading therapy with horizontal-plane viscous resistance targeting weakness and flexion synergy to treat upper limb function in chronic hemiparetic stroke: a randomized clinical trial. Frontiers in neurology, 9, 71.

Elovic, E. P., Munin, M. C., Kaňovský, P., Hanschmann, A., Hiersemenzel, R., & Marciniak, C. (2016). Randomized, placebo-controlled trial of incobotulinumtoxina for upper-limb post-stroke spasticity. Muscle & nerve, 53(3), 415-421.

Emara, T. H., Moustafa, R. R., Elnahas, N. M., Elganzoury, A. M., Abdo, T. A., Mohamed, S. A., & Eletribi, M. A. (2010). Repetitive transcranial magnetic stimulation at 1Hz and 5Hz produces sustained improvement in motor function and disability after ischaemic stroke. European journal of neurology, 17(9), 1203-1209.

Emmerson, K. B., Harding, K. E., & Taylor, N. F. (2017). Home exercise programmes supported by video and automated reminders compared with standard paper-based home exercise programmes in patients with stroke: a randomized controlled trial. Clinical rehabilitation, 31(8), 1068-1077.

Eng, K., Rolin, S., Fazio, R., Biddle, C., O'Grady, M., & Denney, R. (2013). Finger Tapping: Why Can't We Alternate Hands?.Applied Neuropsychology: Adult, 20(3), 187-191.

Eraifej, J., Clark, W., France, B., Desando, S., & Moore, D. (2017). Effectiveness of upper limb functional electrical stimulation after stroke for the improvement of activities of daily living and motor function: a systematic review and meta-analysis. Systematic reviews, 6(1), 40.

Ertelt, D., Small, S., Solodkin, A., Dettmers, C., McNamara, A., Binkofski, F., & Buccino, G. (2007). Action observation has a positive impact on rehabilitation of motor deficits after stroke. Neuroimage, 36, T164-T173.

Etoh, S., Noma, T., Ikeda, K., Jonoshita, Y., Ogata, A., Matsumoto, S., ... & Kawahira, K. (2013). Effects of repetitive trascranial magnetic stimulation on repetitive facilitation exercises of the hemiplegic hand in chronic stroke patients. Journal of rehabilitation medicine, 45(9), 843-847.

Fan, S. C., Su, F. C., Chen, S. S., Hou, W. H., Sun, J. S., Chen, K. H., ... & Hsu, S. H. (2014). Improved intrinsic motivation and muscle activation patterns in reaching task using virtual reality training for stroke rehabilitation: A pilot randomized control trial. Journal of Medical and Biological Engineering, 34(4), 399-407.

Fan, Y. T., Lin, K. C., Liu, H. L., Wu, C. Y., Wai, Y. Y., & Lee, T. H. (2016). Neural correlates of motor recovery after robot-assisted stroke rehabilitation: a case series study. Neurocase, 22(5), 416-425.

Faghri, P. D., & Rodgers, M. M. (1997). The effects of functional neuromuscular stimulation-augmented physical therapy program in the functional recovery of hemiplegic arm in stroke patients. Clinical Kinesiology, 51, 9-15.

Faghri, P. D., Rodgers, M. M., Glaser, R. M., Bors, J. G., Ho, C., & Akuthota, P. (1994). The effects of functional electrical stimulation on shoulder subluxation, arm function recovery, and shoulder pain in hemiplegic stroke patients. Archives of physical medicine and rehabilitation, 75(1), 73-79.

Fan, Y. T., Lin, K. C., Liu, H. L., Wu, C. Y., Wai, Y. Y., & Lee, T. H. (2016). Neural correlates of motor recovery after robot-assisted stroke rehabilitation: a case series study. Neurocase, 22(5), 416-425.

Faria, A. L., Cameirão, M. S., Couras, J. F., Aguiar, J. R., Costa, G. M., & i Badia, S. B. (2018). Combined cognitive-motor rehabilitation in virtual reality improves motor outcomes in chronic stroke–a pilot study. Frontiers in psychology, 9.

Fasoli, S. E., Krebs, H. I., Ferraro, M., Hogan, N., & Volpe, B. T. (2004). Does shorter rehabilitation limit potential recovery poststroke? Neurorehabilitation and neural repair, 18(2), 88-94.

Fayazi, M., Dehkordi, S. N., Dadgoo, M., & Salehi, M. (2012). Test-retest reliability of Motricity Index strength assessments for lower extremity in post stroke hemiparesis. Medical journal of the Islamic Republic of Iran, 26(1), 27.

Ferraro, M., Demaio, J. H., Krol, J., Trudell, C., Rannekleiv, K., Edelstein, L., ... & Krebs, H. I. (2002). Assessing the motor status score: a scale for the evaluation of upper limb motor outcomes in patients after stroke. Neurorehabilitation and neural repair, 16(3), 283-289.

Feys, P., Duportail, M., Kos, D., Van Aschand, P., & Ketelaer, P. (2002). Validity of the TEMPA for the measurement of upper limb function in multiple sclerosis. Clinical rehabilitation, 16(2), 166-173.

Feys, H. M., De Weerdt, W. J., Selz, B. E., Cox Steck, G. A., Spichiger, R., Vereeck, L. E., ... & Van Hoydonck, G. A. (1998). Effect of a therapeutic intervention for the hemiplegic upper limb in the acute phase after stroke: a single-blind, randomized, controlled multicenter trial. Stroke, 29(4), 785-792.

Figlewski, K., Blicher, J. U., Mortensen, J., Severinsen, K. E., Nielsen, J. F., & Andersen, H. (2017). Transcranial direct current stimulation potentiates improvements in functional ability in patients with chronic stroke receiving constraint-induced movement therapy. Stroke, 48(1), 229-232.

Fleming, M. K., Sorinola, I. O., Roberts-Lewis, S. F., Wolfe, C. D., Wellwood, I., & Newham, D. J. (2015). The effect of combined somatosensory stimulation and task-specific training on upper limb function in chronic stroke: a double-blind randomized controlled trial. Neurorehabilitation and Neural Repair, 29(2), 143-152.

Folkerts, M. A., Hijmans, J. M., Elsinghorst, A. L., Mulderij, Y., Murgia, A., & Dekker, R. (2017). Effectiveness and feasibility of eccentric and task-oriented strength training in individuals with stroke. NeuroRehabilitation, 40(4), 459-471.

Franceschini, M., Ceravolo, M. G., Agosti, M., Cavallini, P., Bonassi, S., Dall'Armi, V., ... & Sale, P. (2012). Clinical relevance of action observation in upper-limb stroke rehabilitation: a possible role in recovery of functional dexterity. A randomized clinical trial. Neurorehabilitation and neural repair, 26(5), 456-462.

Francisco, G. E., Boake, C., & Vaughn, A. (2002). Botulinum toxin in upper limb spasticity after acquired brain injury: a randomized trial comparing dilution techniques. American journal of physical medicine & rehabilitation, 81(5), 355-363.

Francisco, G., Chae, J., Chawla, H., Kirshblum, S., Zorowitz, R., Lewis, G., & Pang, S. (1998). Electromyogram-triggered neuromuscular stimulation for improving the arm function of acute stroke survivors: a randomized pilot study. Archives of physical medicine and rehabilitation, 79(5), 570-575.

Fragoso, A. P. S., & Ferreira, A. S. (2012). Immediate effects of acupuncture on biceps brachii muscle function in healthy and post-stroke subjects. Chinese medicine, 7(1), 7.

Fregni, F., Boggio, P. S., Valle, A. C., Rocha, R. R., Duarte, J., Ferreira, M. J., ... & Freedman, S. D. (2006). A sham-controlled trial of a 5-day course of repetitive transcranial magnetic stimulation of the unaffected hemisphere in stroke patients. Stroke, 37(8), 2115-2122.

Fregni, F., Boggio, P. S., Mansur, C. G., Wagner, T., Ferreira, M. J., Lima, M. C., ... & Pascual-Leone, A. (2005). Transcranial direct current stimulation of the unaffected hemisphere in stroke patients. Neuroreport, 16(14), 1551-1555.

Friedman, N., Chan, V., Reinkensmeyer, A. N., Beroukhim, A., Zambrano, G. J., Bachman, M., & Reinkensmeyer, D. J. (2014). Retraining and assessing hand movement after stroke using the MusicGlove: comparison with conventional hand therapy and isometric grip training. Journal of neuroengineering and rehabilitation, 11(1), 76.

Fulk, G., Martin, R., & Page, S. J. (2017). Clinically important difference of the arm motor ability test in Stroke survivors. *Neurorehabilitation and neural repair*, *31*(3), 272-279.

Fusco, A., Assenza, F., Iosa, M., Izzo, S., Altavilla, R., Paolucci, S., & Vernieri, F. (2014). The ineffective role of cathodal tDCS in enhancing the functional motor outcomes in early phase of stroke rehabilitation: an experimental trial. BioMed research international, 2014.

Fusco, A., De Angelis, D., Morone, G., Maglione, L., Paolucci, T., Bragoni, M., & Venturiero, V. (2013). The ABC of tDCS: effects of anodal, bilateral and cathodal montages of transcranial direct current stimulation in patients with stroke—a pilot study. Stroke research and treatment, 2013.

Gabr, U., Levine, P., & Page, S. J. (2005). Home-based electromyography-triggered stimulation in chronic stroke. Clinical rehabilitation, 19(7), 737-745.

Galvão, S. C. B., Dos Santos, R. B. C., Dos Santos, P. B., Cabral, M. E., & Monte-Silva, K. (2014). Efficacy of coupling repetitive transcranial magnetic stimulation and physical therapy to reduce upper-limb spasticity in patients with stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 95(2), 222-229.

Gelber, D. A., Josefczyk, B., Herrman, D., Good, D. C., & Verhulst, S. J. (1995). Comparison of two therapy approaches in the rehabilitation of the pure motor hemiparetic stroke patient. Journal of Neurologic Rehabilitation, 9(4), 191-196.

Gharib, N. M., Aboumousa, A. M., Elowishy, A. A., Rezk-Allah, S. S., & Yousef, F. S. (2015). Efficacy of electrical stimulation as an adjunct to repetitive task practice therapy on skilled hand performance in hemiparetic stroke patients: a randomized controlled trial. Clinical rehabilitation, 29(4), 355-364.

Givon, N., Zeilig, G., Weingarden, H., & Rand, D. (2016). Video-games used in a group setting is feasible and effective to improve indicators of physical activity in individuals with chronic stroke: a randomized controlled trial. Clinical rehabilitation, 30(4), 383-392.

González, N., Bilbao, A., Forjaz, M. J., Ayala, A., Orive, M., Garcia-Gutierrez, S., ... & Quintana, J. M. (2018). Psychometric characteristics of the Spanish version of the Barthel Index. Aging clinical and experimental research, 30(5), 489-497.

Gonzalez, V., Rowson, J., & Yoxall, A. (2017). Analyzing finger interdependencies during the Purdue Pegboard Test and comparative activities of daily living. Journal of Hand Therapy, 30(1), 80-88.

Goodwill, A. M., Teo, W. P., Morgan, P., Daly, R. M., & Kidgell, D. J. (2016). Bihemispheric-tDCS and upper limb rehabilitation improves retention of motor function in chronic stroke: a pilot study. Frontiers in human neuroscience, 10, 258.

Gor-García-Fogeda, M. D., Molina-Rueda, F., Cuesta-Gómez, A., Carratalá-Tejada, M., Alguacil-Diego, I. M., & Miangolarra-Page, J. C. (2014). Scales to assess gross motor function in stroke patients: a systematic review. Archives of physical medicine and rehabilitation, 95(6), 1174-1183.

Gorst, T., Rogers, A., Morrison, S. C., Cramp, M., Paton, J., Freeman, J., & Marsden, J. (2018). The prevalence, distribution, and functional importance of lower limb somatosensory impairments in chronic stroke survivors: a cross sectional observational study. Disability and rehabilitation, 1-8.

Gosman-Hedström, G., Claesson, L., Klingenstierna, U., Carlsson, J., Olausson, B., Frizell, M., ... & Blomstrand, C. (1998). Effects of acupuncture treatment on daily life activities and quality of life: a controlled, prospective, and randomized study of acute stroke patients. Stroke, 29(10), 2100-2108.

Gracies, J. M., Bayle, N., Goldberg, S., & Simpson, D. M. (2014). Botulinum toxin type B in the spastic arm: a randomized, double-blind, placebo-controlled, preliminary study. Archives of physical medicine and rehabilitation, 95(7), 1303-1311.

Gracies, J. M., Brashear, A., Jech, R., McAllister, P., Banach, M., Valkovic, P., ... & Khatkova, S. (2015). Safety and efficacy of abobotulinumtoxinA for hemiparesis in adults with upper limb spasticity after stroke or traumatic brain injury: a double-blind randomised controlled trial. The Lancet Neurology, 14(10), 992-1001.

Graef, P., Michaelsen, S. M., Dadalt, M. L., Rodrigues, D. A., Pereira, F., & Pagnussat, A. S. (2016). Effects of functional and analytical strength training on upper-extremity activity after stroke: a randomized controlled trial. Brazilian journal of physical therapy, (AHEAD), 0-0.

Granger, C. V., Deutsch, A., & Linn, R. T. (1998). Rasch analysis of the Functional Independence Measure (FIM™) mastery test. Archives of physical medicine and rehabilitation, 79(1), 52-57.

Granger, C. V., Cotter, A. C., Hamilton, B. B., & Fiedler, R. C. (1993). Functional assessment scales: a study of persons after stroke. Archives of physical medicine and rehabilitation, 74(2), 133-138.

Guan, Y. Z., Li, J., Zhang, X. W., Wu, S., Du, H., Cui, L. Y., & Zhang, W. H. (2017). Effectiveness of repetitive transcranial magnetic stimulation (rTMS) after acute stroke: A one-year longitudinal randomized trial. CNS neuroscience & therapeutics, 23(12), 940-946.

Gummesson, C., Ward, M. M., & Atroshi, I. (2006). The shortened disabilities of the arm, shoulder and hand questionnaire (Quick DASH): validity and reliability based on responses within the full-length DASH. BMC musculoskeletal disorders, 7(1), 44.

Gurbuz, N., Afsar, S. I., Ayaş, S., & Cosar, S. N. S. (2016). Effect of mirror therapy on upper extremity motor function in stroke patients: a randomized controlled trial. Journal of physical therapy science, 28(9), 2501-2506.

Hammer, A., & Lindmark, B. (2009). Is forced use of the paretic upper limb beneficial? A randomized pilot study during subacute post-stroke recovery. Clinical rehabilitation, 23(5), 424-433.

Hanlan, A., Mills, P., Lipson, R., & Finlayson, H. (2017). Interdisciplinary spasticity management clinic outcomes using the Goal Attainment Scale: A retrospective chart review. Journal of rehabilitation medicine, 49(5), 423-430.

Han, J. S., & Terenius, L. (1982). Neurochemical basis of acupuncture analgesia. Annual review of pharmacology and toxicology, 22(1), 193-220.

HAN, S. K., HAO, H. Y., LIU, F. H., Qing, L. I., LI, X. F., & Wei-Hong, Y. A. N. G. (2015). Effect of meridian sinew row needling combined with dermal needling on spasticity of post-stroke patients with upper limb hemiparalysis: a multi-center randomized controlled trial. World Journal of Acupuncture-Moxibustion, 25(1), 13-18.

Han, K. J., & Kim, J. Y. (2016). The effects of bilateral movement training on upper limb function in chronic stroke patients. Journal of physical therapy science, 28(8), 2299-2302.

Hara, Y., Ogawa, S., Tsujiuchi, K., & Muraoka, Y. (2008). A home-based rehabilitation program for the hemiplegic upper extremity by power-assisted functional electrical stimulation. Disability and Rehabilitation, 30(4), 296-304.

Hara, Y., Ogawa, S., & Muraoka, Y. (2006). Hybrid power-assisted functional electrical stimulation to improve hemiparetic upper-extremity function. American journal of physical medicine & rehabilitation, 85(12), 977-985.

Hayner, K., Gibson, G., & Giles, G. M. (2010). Comparison of constraint-induced movement therapy and bilateral treatment of equal intensity in people with chronic upper-extremity dysfunction after cerebrovascular accident. American Journal of Occupational Therapy, 64(4), 528-539.

Hays, S. A. (2016). Enhancing rehabilitative therapies with vagus nerve stimulation. Neurotherapeutics, 13(2), 382-394.

Hayward, K. S., Barker, R. N., Brauer, S. G., Lloyd, D., Horsley, S. A., & Carson, R. G. (2013). SMART Arm with outcome-triggered electrical stimulation: a pilot randomized clinical trial. Topics in stroke rehabilitation, 20(4), 289-298.

Heckmann, J., Mokrusch, T., Kröckel, A., Warnke, S., Von Stockert, T., & Neundörfer, B. (1997). EMG-triggered electrical muscle stimulation in the treatment of central hemiparesis after a stroke. European journal of physical medicine & rehabilitation, 7(5), 138-141.

Heldner, M. R., Zubler, C., Mattle, H. P., Schroth, G., Weck, A., Mono, M. L., ... & Yan, X. (2013). National Institutes of Health stroke scale score and vessel occlusion in 2152 patients with acute ischemic stroke. Stroke, 44(4), 1153-1157.

Heller, A., Wade, D. T., Wood, V. A., Sunderland, A., Hewer, R. L., & Ward, E. (1987). Arm function after stroke: measurement and recovery over the first three months. Journal of Neurology, Neurosurgery & Psychiatry, 50(6), 714-719.

Hemmen, B., & Seelen, H. A. M. (2007). Effects of movement imagery and electromyography-triggered feedback on arm—hand function in stroke patients in the subacute phase. Clinical Rehabilitation, 21(7), 587-594.

Hendy, A. M., & Kidgell, D. J. (2014). Anodal-tDCS applied during unilateral strength training increases strength and corticospinal excitability in the untrained homologous muscle. Experimental brain research, 232(10), 3243-3252.

Herrold, A. A., Pape, T. L. B., Guernon, A., Mallinson, T., Collins, E., & Jordan, N. (2014). Prescribing multiple neurostimulants during rehabilitation for severe brain injury. The Scientific World Journal, 2014.

Hesse, S., Heß, A., Werner C, C., Kabbert, N., & Buschfort, R. (2014). Effect on arm function and cost of robot-assisted group therapy in subacute patients with stroke and a moderately to severely affected arm: a randomized controlled trial. Clinical rehabilitation, 28(7), 637-647.

Hesse, S., Mach, H., Fröhlich, S., Behrend, S., Werner, C., & Melzer, I. (2012). An early botulinum toxin A treatment in subacute stroke patients may prevent a disabling finger flexor stiffness six months later: a randomized controlled trial. Clinical rehabilitation, 26(3), 237-245.

Hesse, S., Waldner, A., Mehrholz, J., Tomelleri, C., Pohl, M., & Werner, C. (2011). Combined transcranial direct current stimulation and robot-assisted arm training in subacute stroke patients: an exploratory, randomized multicenter trial. Neurorehabilitation and neural repair, 25(9), 838-846.

Hesse, S., Werner, C., Pohl, M., Mehrholz, J., Puzich, U., & Krebs, H. I. (2008). Mechanical arm trainer for the treatment of the severely affected arm after a stroke: a single-blinded randomized trial in two centers. American journal of physical medicine & rehabilitation, 87(10), 779-788.

Hesse, S., Werner, C., Pohl, M., Rueckriem, S., Mehrholz, J., & Lingnau, M. L. (2005). Computerized arm training improves the motor control of the severely affected arm after stroke: a single-blinded randomized trial in two centers. Stroke, 36(9), 1960-1966.

Hesse, S., Reiter, F., Konrad, M., & Jahnke, M. T. (1998). Botulinum toxin type A and short-term electrical stimulation in the treatment of upper limb flexor spasticity after stroke: a randomized, double-blind, placebo-controlled trial. Clinical Rehabilitation, 12(5), 381-388.

Higgins, J., Koski, L., & Xie, H. (2013). Combining rTMS and task-oriented training in the rehabilitation of the arm after stroke: a pilot randomized controlled trial. Stroke Research and Treatment, 2013.

Higgins, J., Mayo, N. E., Desrosiers, J., Salbach, N. M., & Ahmed, S. (2005). Upper-limb function and recovery in the acute phase poststroke. Journal of Rehabilitation Research & Development, 42(1).

Holland, B., & Pokorny, M. E. (2001). Slow stroke back massage: its effect on patients in a rehabilitation setting. Rehabilitation Nursing, 26(5), 182-186.

Hong, X., Lu, Z. K., Teh, I., Nasrallah, F. A., Teo, W. P., Ang, K. K., ... & Chuang, K. H. (2017). Brain plasticity following MI-BCI training combined with tDCS in a randomized trial in chronic subcortical stroke subjects: a preliminary study. Scientific reports, 7(1), 9222.

Hopwood, V., Lewith, G., Prescott, P., & Campbell, M. J. (2008). Evaluating the efficacy of acupuncture in defined aspects of stroke recovery. Journal of neurology, 255(6), 858.

Horvat, M., Pitetti, K. H., & Croce, R. (1997). Isokinetic torque, average power, and flexion/extension ratios in nondisabled adults and adults with mental retardation. Journal of Orthopaedic & Sports Physical Therapy, 25(6), 395-399.

Hosomi, K., Morris, S., Sakamoto, T., Taguchi, J., Maruo, T., Kageyama, Y., ... & Saitoh, Y. (2016). Daily repetitive transcranial magnetic stimulation for poststroke upper limb paresis in the subacute period. Journal of Stroke and Cerebrovascular Diseases, 25(7), 1655-1664.

Houwink, A., Roorda, L. D., Smits, W., Molenaar, I. W., & Geurts, A. C. (2011). Measuring upper limb capacity in patients after stroke: reliability and validity of the stroke upper limb capacity scale. Archives of physical medicine and rehabilitation, 92(9), 1418-1422.

Hsieh, Y. W., Wu, C. Y., Wang, W. E., Lin, K. C., Chang, K. C., Chen, C. C., & Liu, C. T. (2017). Bilateral robotic priming before task-oriented approach in subacute stroke rehabilitation: a pilot randomized controlled trial. Clinical rehabilitation, 31(2), 225-233.

Hsieh, Y. W., Liing, R. J., Lin, K. C., Wu, C. Y., Liou, T. H., Lin, J. C., & Hung, J. W. (2016). Sequencing bilateral robot-assisted arm therapy and constraint-induced therapy improves reach to press and trunk kinematics in patients with stroke. Journal of neuroengineering and rehabilitation, 13(1), 31.

Hsieh, Y. W., Lin, K. C., Horng, Y. S., Wu, C. Y., Wu, T. C., & Ku, F. L. (2014). Sequential combination of robot-assisted therapy and constraint-induced therapy in stroke rehabilitation: a randomized controlled trial. Journal of neurology, 261(5), 1037-1045.

Hsieh, R. L., Wang, L. Y., & Lee, W. C. (2007). Additional therapeutic effects of electroacupuncture in conjunction with conventional rehabilitation for patients with first-ever ischaemic stroke. Journal of Rehabilitation Medicine, 39(3), 205-211.

Hsieh, Y. W., Wu, C. Y., Lin, K. C., Yao, G., Wu, K. Y., & Chang, Y. J. (2012). Dose–response relationship of robot-assisted stroke motor rehabilitation: the impact of initial motor status. Stroke, 43(10), 2729-2734.

Hsieh, Y. W., Wu, C. Y., Liao, W. W., Lin, K. C., Wu, K. Y., & Lee, C. Y. (2011). Effects of treatment intensity in upper limb robot-assisted therapy for chronic stroke: a pilot randomized controlled trial. Neurorehabilitation and neural repair, 25(6), 503-511.

Hsing, W. T., Imamura, M., Weaver, K., Fregni, F., & Azevedo Neto, R. S. (2012). Clinical effects of scalp electrical acupuncture in stroke: a sham-controlled randomized clinical trial. The Journal of Alternative and Complementary Medicine, 18(4), 341-346.

Hsu, S. S., Hu, M. H., Wang, Y. H., Yip, P. K., Chiu, J. W., & Hsieh, C. L. (2010). Dose-response relation between neuromuscular electrical stimulation and upper-extremity function in patients with stroke. Stroke, 41(4), 821-824.

Hsu, Y. F., Huang, Y. Z., Lin, Y. Y., Tang, C. W., Liao, K. K., Lee, P. L., ... & Lee, I. H. (2013). Intermittent theta burst stimulation over ipsilesional primary motor cortex of subacute ischemic stroke patients: a pilot study. Brain stimulation, 6(2), 166-174.

Hubbard, I. J., Carey, L. M., Budd, T. W., Levi, C., McElduff, P., Hudson, S., ... & Parsons, M. W. (2015). A randomized controlled trial of the effect of early upper-limb training on stroke recovery and brain activation. Neurorehabilitation and neural repair, 29(8), 703-713.

Huang, M., Harvey, R. L., Ellen Stoykov, M., Ruland, S., Weinand, M., Lowry, D., & Levy, R. (2008). Cortical stimulation for upper limb recovery following ischemic stroke: a small phase II pilot study of a fully implanted stimulator. Topics in stroke rehabilitation, 15(2), 160-172.

Hung, C. S., Hsieh, Y. W., Wu, C. Y., Lin, Y. T., Lin, K. C., & Chen, C. L. (2016). The effects of combination of robot-assisted therapy with task-specific or impairment-oriented training on motor function and quality of life in chronic stroke. PM&R, 8(8), 721-729.

Huseyinsinoglu, B. E., Ozdincler, A. R., & Krespi, Y. (2012). Bobath Concept versus constraint-induced movement therapy to improve arm functional recovery in stroke patients: a randomized controlled trial. Clinical rehabilitation, 26(8), 705-715.

Hunter, S. M., Johansen-Berg, H., Ward, N., Kennedy, N. C., Chandler, E., Weir, C. J., ... & Leavey, N. M. (2018). Functional strength training and movement performance therapy for upper limb recovery early poststroke—efficacy, neural correlates, predictive markers, and cost-effectiveness: FAST-INdiCATE Trial. Frontiers in Neurology, 8, 733.

Hunter, S. M., Hammett, L., Ball, S., Smith, N., Anderson, C., Clark, A., ... & Pomeroy, V. M. (2011). Dose–response study of mobilisation and tactile stimulation therapy for the upper extremity early after stroke: a phase I trial. Neurorehabilitation and neural repair, 25(4), 314-322.

Hu, H. H., Chung, C., Liu, T. J., Chen, R. C., Chen, C. H., Chou, P., ... & Tsuei, J. T. (1993). A randomized controlled trial on the treatment for acute partial ischemic stroke with acupuncture. Neuroepidemiology, 12(2), 106-113.

Hu, X. L., Tong, R. K. Y., Ho, N. S., Xue, J. J., Rong, W., & Li, L. S. (2015). Wrist rehabilitation assisted by an electromyography-driven neuromuscular electrical stimulation robot after stroke. Neurorehabilitation and neural repair, 29(8), 767-776.

Hu, X. L., Tong, K. Y., Song, R., Zheng, X. J., & Leung, W. W. (2009). A comparison between electromyography-driven robot and passive motion device on wrist rehabilitation for chronic stroke. Neurorehabilitation and neural repair, 23(8), 837-846.

Hwang, C. H., Seong, J. W., & Son, D. S. (2012). Individual finger synchronized robot-assisted hand rehabilitation in subacute to chronic stroke: a prospective randomized clinical trial of efficacy. Clinical Rehabilitation, 26(8), 696-704.

Hummel, F., Celnik, P., Giraux, P., Floel, A., Wu, W. H., Gerloff, C., & Cohen, L. G. (2005). Effects of non-invasive cortical stimulation on skilled motor function in chronic stroke. Brain, 128(3), 490-499.

Ikuno, K., Kawaguchi, S., Kitabeppu, S., Kitaura, M., Tokuhisa, K., Morimoto, S., ... & Shomoto, K. (2012). Effects of peripheral sensory nerve stimulation plus task-oriented training on upper

extremity function in patients with subacute stroke: a pilot randomized crossover trial. Clinical rehabilitation, 26(11), 999-1009.

Ilić, N. V., Dubljanin-Raspopović, E., Nedeljković, U., Tomanović-Vujadinović, S., Milanović, S. D., Petronić-Marković, I., & Ilić, T. V. (2016). Effects of anodal tDCS and occupational therapy on fine motor skill deficits in patients with chronic stroke. Restorative neurology and neuroscience, 34(6), 935-945.

Invernizzi, M., Negrini, S., Carda, S., Lanzotti, L., Cisari, C., & Baricich, A. (2013). The value of adding mirror therapy for upper limb motor recovery of subacute stroke patients: a randomized controlled trial. Eur J Phys Rehabil Med, 49(3), 311-7.

Iruthayarajah, J., McIntyre, A., Cotoi, A., Macaluso, S., & Teasell, R. (2017). The use of virtual reality for balance among individuals with chronic stroke: a systematic review and meta-analysis. Topics in stroke rehabilitation, 24(1), 68-79.

Jahangir, A. W., Tan, H. J., Norlinah, M. I., Nafisah, W. Y., Ramesh, S., Hamidon, B. B., & Raymond, A. A. (2007). Intramuscular injection of botulinum toxin for the treatment of wrist and finger spasticity after stroke. Medical Journal of Malaysia, 62(4), 319.

Jang, S. H., You, S. H., Hallett, M., Cho, Y. W., Park, C. M., Cho, S. H., ... & Kim, T. H. (2005). Cortical reorganization and associated functional motor recovery after virtual reality in patients with chronic stroke: an experimenter-blind preliminary study. Archives of physical medicine and rehabilitation, 86(11), 2218-2223.

Jeon, S., Kim, Y., Jung, K., & Chung, Y. (2017). The effects of electromyography-triggered electrical stimulation on shoulder subluxation, muscle activation, pain, and function in persons with stroke: A pilot study. NeuroRehabilitation, 40(1), 69-75.

Jeon, H. J., An, S., Yoo, J., Park, N. H., & Lee, K. H. (2016). The effect of Monkey Chair and Band exercise system on shoulder range of motion and pain in post-stroke patients with hemiplegia. Journal of physical therapy science, 28(8), 2232-2237.

Jongbloed, L., Stacey, S., & Brighton, C. (1989). Stroke rehabilitation: sensorimotor integrative treatment versus functional treatment. The American Journal of Occupational Therapy, 43(6), 391-397.

Ji, S. G., Cha, H. G., & Kim, M. K. (2014). Stroke recovery can be enhanced by using repetitive transcranial magnetic stimulation combined with mirror therapy. Journal of Magnetics, 19(1), 28-31.

Jonsdottir, J., Thorsen, R., Aprile, I., Galeri, S., Spannocchi, G., Beghi, E., ... & Ferrarin, M. (2017). Arm rehabilitation in post stroke subjects: A randomized controlled trial on the efficacy of myoelectrically driven FES applied in a task-oriented approach. PloS one, 12(12), e0188642.

Jung, K., Jung, J., In, T., Kim, T., & Cho, H. Y. (2017). The influence of Task-Related Training combined with Transcutaneous Electrical Nerve Stimulation on paretic upper limb muscle activation in patients with chronic stroke. NeuroRehabilitation, 40(3), 315-323.

Jung, Y. J., Hong, J. H., Kwon, H. G., Song, J. C., Kim, C., Park, S., ... & Jang, S. H. (2011). The effect of a stretching device on hand spasticity in chronic hemiparetic stroke patients. NeuroRehabilitation, 29(1), 53-59.

Jun, E. M., Roh, Y. H., & Kim, M. J. (2013). The effect of music-movement therapy on physical and psychological states of stroke patients. Journal of clinical nursing, 22(1-2), 22-31.

Kahn, L. E., Zygman, M. L., Rymer, W. Z., & Reinkensmeyer, D. J. (2006). Robot-assisted reaching exercise promotes arm movement recovery in chronic hemiparetic stroke: a randomized controlled pilot study. Journal of neuroengineering and rehabilitation, 3(1), 12.

Kaji, R., Osako, Y., Suyama, K., Maeda, T., Uechi, Y., Iwasaki, M., & GSK1358820 Spasticity Study Group. (2010). Botulinum toxin type A in post-stroke upper limb spasticity. Current medical research and opinion, 26(8), 1983-1992.

Kang, H. S., Sok, S. R., & Kang, J. S. (2009). Effects of Meridian acupressure for stroke patients in Korea. Journal of clinical nursing, 18(15), 2145-2152.

Karakus, D., Ersoz, M., Koyuncu, G., Turk, D., Sasmaz, F. M., & Akyuz, M. (2013). Effects of functional electrical stimulation on wrist function and spasticity in stroke: a randomized controlled study/Inmede fonksiyonel elektrik stimulasyonunun el bilegi fonksiyonlari ve spastisiteye etkisi: randomize kontrollu bir calisma. Turkish Journal of Physical Medicine and Rehabilitation, 59(2), 97-103.

Kattenstroth, J. C., Kalisch, T., Sczesny-Kaiser, M., Greulich, W., Tegenthoff, M., & Dinse, H. R. (2018). Daily repetitive sensory stimulation of the paretic hand for the treatment of sensorimotor deficits in patients with subacute stroke: RESET, a randomized, sham-controlled trial. BMC neurology, 18(1), 2.

Kattenstroth, J. C., Kalisch, T., Kowalewski, R., Tegenthoff, M., & Dinse, H. R. (2013). Quantitative assessment of joint position sense recovery in subacute stroke patients: a pilot study. Journal of rehabilitation medicine, 45(10), 1004-1009.

Khan, C. M., Oesch, P. R., Gamper, U. N., Kool, J. P., & Beer, S. (2011). Potential effectiveness of three different treatment approaches to improve minimal to moderate arm and hand function after stroke–a pilot randomized clinical trial. Clinical rehabilitation, 25(11), 1032-1041.

Khedr, E. M., Shawky, O. A., El-Hammady, D. H., Rothwell, J. C., Darwish, E. S., Mostafa, O. M., & Tohamy, A. M. (2013). Effect of anodal versus cathodal transcranial direct current stimulation on stroke rehabilitation: a pilot randomized controlled trial. Neurorehabilitation and neural repair, 27(7), 592-601.

Khedr, E. M., Etraby, A. E., Hemeda, M., Nasef, A. M., & Razek, A. A. E. (2010). Long-term effect of repetitive transcranial magnetic stimulation on motor function recovery after acute ischemic stroke. Acta Neurologica Scandinavica, 121(1), 30-37.

Khedr, E. M., Abdel-Fadeil, M. R., Farghali, A., & Qaid, M. (2009). Role of 1 and 3 Hz repetitive transcranial magnetic stimulation on motor function recovery after acute ischaemic stroke. European journal of neurology, 16(12), 1323-1330.

Khedr, E. M., Ahmed, M. A., Fathy, N., & Rothwell, J. C. (2005). Therapeutic trial of repetitive transcranial magnetic stimulation after acute ischemic stroke. Neurology, 65(3), 466-468.

Kong, K. H., Loh, Y. J., Thia, E., Chai, A., Ng, C. Y., Soh, Y. M., ... & Tjan, S. Y. (2016). Efficacy of a virtual reality commercial gaming device in upper limb recovery after stroke: a randomized, controlled study. Topics in stroke rehabilitation, 23(5), 333-340.

Kimberley, T. J., Lewis, S. M., Auerbach, E. J., Dorsey, L. L., Lojovich, J. M., & Carey, J. R. (2004). Electrical stimulation driving functional improvements and cortical changes in subjects with stroke. Experimental Brain Research, 154(4), 450-460

Kim, D. Y., Lim, J. Y., Kang, E. K., You, D. S., Oh, M. K., Oh, B. M., & Paik, N. J. (2010). Effect of transcranial direct current stimulation on motor recovery in patients with subacute stroke. American journal of physical medicine & rehabilitation, 89(11), 879-886.

Kim, J. O., Lee, J., & Lee, B. H. (2017). Effect of scapular stabilization exercise during standing on upper limb function and gait ability of stroke patients. Journal of neurosciences in rural practice, 8(4), 540.

Kim, G. J., Hinojosa, J., Rao, A. K., Batavia, M., & O'Dell, M. W. (2017). Randomized trial on the effects of attentional focus on motor training of the upper extremity using robotics with individuals after chronic stroke. Archives of physical medicine and rehabilitation, 98(10), 1924-1931.

Kim, M. K. (2014). Repetitive Transcranial Magnetic Stimulation Combined with Task Oriented Training to Improve Upper Extremity Function After Stroke. Journal of Magnetics, 19(2), 170-173.

Kim, S. H., Park, J. H., Jung, M. Y., & Yoo, E. Y. (2016). Effects of Task-Oriented Training as an Added Treatment to Electromyogram-Triggered Neuromuscular Stimulation on Upper Extremity Function in Chronic Stroke Patients. Occupational therapy international, 23(2), 165-174.

Kim, K., Lee, S., Kim, D., Lee, K., & Kim, Y. (2016). Effects of mirror therapy combined with motor tasks on upper extremity function and activities daily living of stroke patients. Journal of physical therapy science, 28(2), 483-487.

Kim, C. Y., Lee, J. S., Lee, J. H., Kim, Y. G., Shin, A. R., Shim, Y. H., & Ha, H. K. (2015). Effect of spatial target reaching training based on visual biofeedback on the upper extremity function of hemiplegic stroke patients. Journal of physical therapy science, 27(4), 1091-1096.

Kim, D. H., Shin, J. C., Jung, S., Jung, T. M., & Kim, D. Y. (2015). Effects of intermittent theta burst stimulation on spasticity after stroke. Neuroreport, 26(10), 561.

Kim, E., & Kim, K. (2015). Effect of purposeful action observation on upper extremity function in stroke patients. Journal of physical therapy science, 27(9), 2867-2869.

Kim, E. B., & Kim, Y. D. (2015). Effects of kinesiology taping on the upper-extremity function and activities of daily living in patients with hemiplegia. *Journal of physical therapy science*, *27*(5), 1455-1457.

Kim, E. H., Jang, M. C., Seo, J. P., Jang, S. H., Song, J. C., & Jo, H. M. (2013). The effect of a hand-stretching device during the management of spasticity in chronic hemiparetic stroke patients. Annals of Rehabilitation Medicine, 37(2), 235-240.

Kim, J. H., & Lee, B. H. (2015). Mirror therapy combined with biofeedback functional electrical stimulation for motor recovery of upper extremities after stroke: a pilot randomized controlled trial. Occupational therapy international, 22(2), 51-60.

Kim, J., & Yim, J. (2017). Effects of an Exercise Protocol for Improving Handgrip Strength and Walking Speed on Cognitive Function in Patients with Chronic Stroke. Medical science monitor: international medical journal of experimental and clinical research, 23, 5402.

Kim, G. J., Hinojosa, J., Rao, A. K., Batavia, M., & O'Dell, M. W. (2017). Randomized trial on the effects of attentional focus on motor training of the upper extremity using robotics with individuals after chronic stroke. *Archives of physical medicine and rehabilitation*, *98*(10), 1924-1931.

Kim, T. H., In, T. S., & Cho, H. Y. (2013). Task-related training combined with transcutaneous electrical nerve stimulation promotes upper limb functions in patients with chronic stroke. The Tohoku journal of experimental medicine, 231(2), 93-100.

Kim, D. Y., Ohn, S. H., Yang, E. J., Park, C. I., & Jung, K. J. (2009). Enhancing motor performance by anodal transcranial direct current stimulation in subacute stroke patients. American journal of physical medicine & rehabilitation, 88(10), 829-836.

Kim, W. S., Cho, S., Park, S. H., Lee, J. Y., Kwon, S., & Paik, N. J. (2018). A low cost kinect-based virtual rehabilitation system for inpatient rehabilitation of the upper limb in patients with subacute stroke: A randomized, double-blind, sham-controlled pilot trial. Medicine, 97(25).

King, T. I. (1996). The effect of neuromuscular electrical stimulation in reducing tone. The American journal of occupational therapy: official publication of the American Occupational Therapy Association, 50(1), 62.

Kiper, P., Szczudlik, A., Agostini, M., Opara, J., Nowobilski, R., Ventura, L., ... & Turolla, A. (2018). Virtual reality for upper limb rehabilitation in subacute and chronic stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 99(5), 834-842.

Kiper, P., Agostini, M., Luque-Moreno, C., Tonin, P., & Turolla, A. (2014). Reinforced feedback in virtual environment for rehabilitation of upper extremity dysfunction after stroke: preliminary data from a randomized controlled trial. BioMed research international, 2014.

Kjendahl, A., Säliström, S., Østen, P. E., Stanghelle, J. K., & Borchgrevink, C. F. (1997). A one year follow-up study on the effects of acupuncture in the treatment of stroke patients in the subacute stage: a randomized, controlled study. Clinical Rehabilitation, 11(3), 192-200.

Klaiput, A., & Kitisomprayoonkul, W. (2009). Increased pinch strength in acute and subacute stroke patients after simultaneous median and ulnar sensory stimulation. Neurorehabilitation and neural repair, 23(4), 351-356.

Klamroth-Marganska, V., Blanco, J., Campen, K., Curt, A., Dietz, V., Ettlin, T., ... & Luft, A. (2014). Three-dimensional, task-specific robot therapy of the arm after stroke: a multicentre, parallel-group randomised trial. The Lancet Neurology, 13(2), 159-166.

Knutson, J. S., Harley, M. Y., Hisel, T. Z., Hogan, S. D., Maloney, M. M., & Chae, J. (2012). Contralaterally controlled functional electrical stimulation for upper extremity hemiplegia: an early-phase randomized clinical trial in subacute stroke patients. Neurorehabilitation and neural repair, 26(3), 239-246.

Knutson, J. S., Harley, M. Y., Hisel, T. Z., & Chae, J. (2007). Improving hand function in stroke survivors: a pilot study of contralaterally controlled functional electric stimulation in chronic hemiplegia. Archives of physical medicine and rehabilitation, 88(4), 513-520.

Koh, C. L., Lin, J. H., Jeng, J. S., Huang, S. L., & Hsieh, C. L. (2017). Effects of Transcranial direct current stimulation with sensory modulation on stroke motor rehabilitation: A randomized controlled trial. Archives of physical medicine and rehabilitation, 98(12), 2477-2484.

Kojima, K., Ikuno, K., Morii, Y., Tokuhisa, K., Morimoto, S., & Shomoto, K. (2014). Feasibility study of a combined treatment of electromyography-triggered neuromuscular stimulation and mirror therapy in stroke patients: a randomized crossover trial. NeuroRehabilitation, 34(2), 235-244.

Kollen, B. J., Lennon, S., Lyons, B., Wheatley-Smith, L., Scheper, M., Buurke, J. H., ... & Kwakkel, G. (2009). The effectiveness of the Bobath concept in stroke rehabilitation: What is the evidence?

Kowalczewski, J., Gritsenko, V., Ashworth, N., Ellaway, P., & Prochazka, A. (2007). Upper-extremity functional electric stimulation–assisted exercises on a workstation in the subacute phase of stroke recovery. Archives of physical medicine and rehabilitation, 88(7), 833-839.

Krasny-Pacini, A., Evans, J., Sohlberg, M. M., & Chevignard, M. (2016). Proposed criteria for appraising goal attainment scales used as outcome measures in rehabilitation research. Archives of Physical Medicine and Rehabilitation, 97(1), 157-170.

Krebs, H. I., Palazzolo, J. J., Dipietro, L., Ferraro, M., Krol, J., Rannekleiv, K., ... & Hogan, N. (2003). Rehabilitation robotics: Performance-based progressive robot-assisted therapy. Autonomous robots, 15(1), 7-20.

Krewer, C., Hartl, S., Müller, F., & Koenig, E. (2014). Effects of repetitive peripheral magnetic stimulation on upper-limb spasticity and impairment in patients with spastic hemiparesis: a randomized, double-blind, sham-controlled study. Archives of physical medicine and rehabilitation, 95(6), 1039-1047.

Kristensen, O. H., Stenager, E., & Dalgas, U. (2017). Muscle strength and poststroke hemiplegia: a systematic review of muscle strength assessment and muscle strength impairment. Archives of physical medicine and rehabilitation, 98(2), 368-380.

Kuk, E. J., Kim, J. M., Oh, D. W., & Hwang, H. J. (2016). Effects of action observation therapy on hand dexterity and EEG-based cortical activation patterns in patients with post-stroke hemiparesis. Topics in stroke rehabilitation, 23(5), 318-325.

Kutner, N. G., Zhang, R., Butler, A. J., Wolf, S. L., & Alberts, J. L. (2010). Quality-of-life change associated with robotic-assisted therapy to improve hand motor function in patients with subacute stroke: a randomized clinical trial. Physical therapy, 90(4), 493-504.

Kwakkel, G., Winters, C., Van Wegen, E. E., Nijland, R. H., Van Kuijk, A. A., Visser-Meily, A., ... & Meskers, C. G. (2016). Effects of unilateral upper limb training in two distinct prognostic groups early after stroke: the EXPLICIT-stroke randomized clinical trial. Neurorehabilitation and neural repair, 30(9), 804-816.

Lam, T. K., Dawson, D. R., Honjo, K., Ross, B., Binns, M. A., Stuss, D. T., ... & Chen, J. L. (2018). Neural coupling between contralesional motor and frontoparietal networks correlates with motor ability in individuals with chronic stroke. Journal of the neurological sciences, 384, 21-29.

Lang, C. E., Strube, M. J., Bland, M. D., Waddell, K. J., Cherry-Allen, K. M., Nudo, R. J., ... & Birkenmeier, R. L. (2016). Dose response of task-specific upper limb training in people at least 6 months poststroke: A phase II, single-blind, randomized, controlled trial. Annals of neurology, 80(3), 342-354.

Langlois, S., Pederson, L., & MacKinnon, J. R. (1991). The Effects of Splinting on the Spastic Hemiplegic is Hand: Report of a Feasibility Study. Canadian Journal of Occupational Therapy, 58(1), 17-25.

Langhammer, B., & Stanghelle, J. K. (2011). Can physiotherapy after stroke based on the Bobath concept result in improved quality of movement compared to the motor relearning programme. Physiotherapy Research International, 16(2), 69-80.

Lannin, N. A., Cusick, A., Hills, C., Kinnear, B., Vogel, K., Matthews, K., & Bowring, G. (2016). Upper limb motor training using a Saebo™ orthosis is feasible for increasing task-specific practice in hospital after stroke. Australian occupational therapy journal, 63(6), 364-372.

Lannin, N. A., Cusick, A., McCluskey, A., & Herbert, R. D. (2007). Effects of splinting on wrist contracture after stroke: a randomized controlled trial. Stroke, 38(1), 111-116.

Lannin, N. A., Horsley, S. A., Herbert, R., McCluskey, A., & Cusick, A. (2003). Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. Archives of physical medicine and rehabilitation, 84(2), 297-302.

Laver, K. E., Lange, B., George, S., Deutsch, J. E., Saposnik, G., & Crotty, M. (2017). Virtual reality for stroke rehabilitation. Cochrane database of systematic reviews, (11).

Lee, S. J., & Chun, M. H. (2014). Combination transcranial direct current stimulation and virtual reality therapy for upper extremity training in patients with subacute stroke. Archives of physical medicine and rehabilitation, 95(3), 431-438.

Lee, D., Lee, M., Lee, K., & Song, C. (2014). Asymmetric training using virtual reality reflection equipment and the enhancement of upper limb function in stroke patients: a randomized controlled trial. Journal of stroke and cerebrovascular diseases, 23(6), 1319-1326.

Lee, K. W., Kim, S. B., Lee, J. H., Lee, S. J., & Yoo, S. W. (2016). Effect of upper extremity robot-assisted exercise on spasticity in stroke patients. Annals of rehabilitation medicine, 40(6), 961.

Lee, M., Son, J., Kim, J., Pyun, S. B., Eun, S. D., & Yoon, B. (2016). Comparison of individualized virtual reality-and group-based rehabilitation in older adults with chronic stroke in community settings: a pilot randomized controlled trial. European Journal of Integrative Medicine, 8(5), 738-746.

Lee, M. M., Shin, D. C., & Song, C. H. (2016). Canoe game-based virtual reality training to improve trunk postural stability, balance, and upper limb motor function in subacute stroke

patients: a randomized controlled pilot study. Journal of physical therapy science, 28(7), 2019-2024.

Lee, J. S., Kim, C. Y., & Kim, H. D. (2016). Short-term effects of whole-body vibration combined with task-related training on upper extremity function, spasticity, and grip strength in subjects with poststroke hemiplegia: A pilot randomized controlled trial. American journal of physical medicine & rehabilitation, 95(8), 608-617.

Lee, M. J., Lee, J. H., Koo, H. M., & Lee, S. M. (2017). Effectiveness of bilateral arm training for improving extremity function and activities of daily living performance in hemiplegic patients. Journal of Stroke and Cerebrovascular Diseases, 26(5), 1020-1025.

Lee, M. M., Lee, K. J., & Song, C. H. (2018). Game-based virtual reality canoe paddling training to improve postural balance and upper extremity function: A preliminary randomized controlled study of 30 patients with subacute stroke. Medical science monitor: international medical journal of experimental and clinical research, 24, 2590.

Lee, S., Kim, Y., & Lee, B. H. (2016). Effect of Virtual Reality-based Bilateral Upper Extremity Training on Upper Extremity Function after Stroke: A Randomized Controlled Clinical Trial. Occupational therapy international, 23(4), 357-368.

Lee, S. J., & Chun, M. H. (2014). Combination transcranial direct current stimulation and virtual reality therapy for upper extremity training in patients with subacute stroke. Archives of physical medicine and rehabilitation, 95(3), 431-438.

Lee, Y. Y., Lin, K. C., Cheng, H. J., Wu, C. Y., Hsieh, Y. W., & Chen, C. K. (2015). Effects of combining robot-assisted therapy with neuromuscular electrical stimulation on motor impairment, motor and daily function, and quality of life in patients with chronic stroke: a double-blinded randomized controlled trial. Journal of neuroengineering and rehabilitation, 12(1), 96.

Lee, D. G., & Lee, D. Y. (2015). Effects of adjustment of transcranial direct current stimulation on motor function of the upper extremity in stroke patients. Journal of physical therapy science, 27(11), 3511-3513.

Lee, Y. Y., Lin, K. C., Wu, C. Y., Liao, C. H., Lin, J. C., & Chen, C. L. (2015). Combining afferent stimulation and mirror therapy for improving muscular, sensorimotor, and daily functions after chronic stroke: A randomized, placebo-controlled study. American journal of physical medicine & rehabilitation, 94(10S), 859-868.

Lee, D., Roh, H., Park, J., Lee, S., & Han, S. (2013). Drinking behavior training for stroke patients using action observation and practice of upper limb function. J Phys Ther Sci, 25(5), 611-614.

Lefebvre, S., Dricot, L., Laloux, P., Gradkowski, W., Desfontaines, P., Evrard, F., ... & Vandermeeren, Y. (2014). Neural substrates underlying stimulation-enhanced motor skill learning after stroke. Brain, 138(1), 149-163.

Lefebvre, S., Thonnard, J. L., Laloux, P., Peeters, A., Jamart, J., & Vandermeeren, Y. (2014). Single session of dual-tDCS transiently improves precision grip and dexterity of the paretic hand after stroke. Neurorehabilitation and Neural Repair, 28(2), 100-110.

Lefebvre, S., Laloux, P., Peeters, A., Desfontaines, P., Jamart, J., & Vandermeeren, Y. (2013). Dual-tDCS enhances online motor skill learning and long-term retention in chronic stroke patients. Frontiers in human neuroscience, 6, 343.

Lemmens, R. J., Timmermans, A. A., Janssen-Potten, Y. J., Pulles, S. A., Geers, R. P., Bakx, W. G., ... & Seelen, H. A. (2014). Accelerometry measuring the outcome of robot-supported upper limb training in chronic stroke: a randomized controlled trial. PloS one, 9(5), e96414.

Letswaart, M., Johnston, M., Dijkerman, H. C., Joice, S., Scott, C. L., MacWalter, R. S., & Hamilton, S. J. (2011). Mental practice with motor imagery in stroke recovery: randomized controlled trial of efficacy. Brain, 134(5), 1373-1386.

Levy, R. M., Harvey, R. L., Kissela, B. M., Winstein, C. J., Lutsep, H. L., Parrish, T. B., ... & Venkatesan, L. (2016). Epidural electrical stimulation for stroke rehabilitation: results of the prospective, multicenter, randomized, single-blinded everest trial. Neurorehabilitation and neural repair, 30(2), 107-119.

Levy, R., Ruland, S., Weinand, M., Lowry, D., Dafer, R., & Bakay, R. (2008). Cortical stimulation for the rehabilitation of patients with hemiparetic stroke: a multicenter feasibility study of safety and efficacy. Journal of neurosurgery, 108(4), 707-714.

Liao, L. R., Ng, G. Y., Jones, A. Y., Chung, R. C., & Pang, M. Y. (2015). Effects of vibration intensity, exercise, and motor impairment on leg muscle activity induced by whole-body vibration in people with stroke. Physical therapy, 95(12), 1617-1627.

Liao, W. W., Wu, C. Y., Hsieh, Y. W., Lin, K. C., & Chang, W. Y. (2012). Effects of robot-assisted upper limb rehabilitation on daily function and real-world arm activity in patients with chronic stroke: a randomized controlled trial. *Clinical Rehabilitation*, *26*(2), 111-120.

Liepert, J., Zittel, S., & Weiller, C. (2007). Improvement of dexterity by single session low-frequency repetitive transcranial magnetic stimulation over the contralesional motor cortex in acute stroke: a double-blind placebo-controlled crossover trial. Restorative neurology and neuroscience, 25(5, 6), 461-465.

Li, J., Meng, X. M., Li, R. Y., Zhang, R., Zhang, Z., & Du, Y. F. (2016). Effects of different frequencies of repetitive transcranial magnetic stimulation on the recovery of upper limb motor dysfunction in patients with subacute cerebral infarction. Neural regeneration research, 11(10), 1584.

Li, Q., Tian, F. L., Liu, G. R., Zheng, D. S., Chen, J. M., Ma, S. R., ... & Li, X. Q. (2014). Impact on the gait time cycle of ischemic stroke in the treatment with yin-yang respiratory reinforcing and reducing needling technique. Zhongguo zhen jiu= Chinese acupuncture & moxibustion, 34(3), 237-240.

Li, F., Wu, Y., & Li, X. (2014b). Test-retest reliability and inter-rater reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in hemiplegic patients with stroke. Eur J Phys Rehabil Med, 50(1), 9-15.

Li, N., Tian, F., Wang, C., Yu, P., Zhou, X., Wen, Q., ... & Huang, L. (2012). Therapeutic effect of acupuncture and massage for shoulder-hand syndrome in hemiplegia patients: a clinical two-center randomized controlled trial. Journal of Traditional Chinese Medicine, 32(3), 343-349.

Lima, R. C. M., Michaelsen, S. M., Nascimento, L. R., Polese, J. C., Pereira, N. D., & Teixeira-Salmela, L. F. (2014). Addition of trunk restraint to home-based modified constraint-induced movement therapy does not bring additional benefits in chronic stroke individuals with mild and moderate upper limb impairments: A pilot randomized controlled trial. NeuroRehabilitation, 35(3), 391-404.

Lim, K. B., Lee, H. J., Yoo, J., Yun, H. J., & Hwang, H. J. (2016). Efficacy of mirror therapy containing functional tasks in poststroke patients. Annals of rehabilitation medicine, 40(4), 629.

Linacre, J. M., Heinemann, A. W., Wright, B. D., Granger, C. V., & Hamilton, B. B. (1994). The structure and stability of the Functional Independence Measure. Archives of physical medicine and rehabilitation, 75(2), 127-132.

Lin, C. H., Chou, L. W., Luo, H. J., Tsai, P. Y., Lieu, F. K., Chiang, S. L., & Sung, W. H. (2015). Effects of computer-aided interlimb force coupling training on paretic hand and arm motor control following chronic stroke: a randomized controlled trial. PloS one, 10(7), e0131048.

Lin, K. C., Chen, Y. T., Huang, P. C., Wu, C. Y., Huang, W. L., Yang, H. W., ... & Lu, H. J. (2014). Effect of mirror therapy combined with somatosensory stimulation on motor recovery and daily function in stroke patients: A pilot study. Journal of the Formosan Medical Association, 113(7), 422-428.

Lin, K. C., Huang, P. C., Chen, Y. T., Wu, C. Y., & Huang, W. L. (2014). Combining afferent stimulation and mirror therapy for rehabilitating motor function, motor control, ambulation, and daily functions after stroke. Neurorehabilitation and neural repair, 28(2), 153-162.

Lin, K. C., Chen, Y. A., Chen, C. L., Wu, C. Y., & Chang, Y. F. (2010). The effects of bilateral arm training on motor control and functional performance in chronic stroke: a randomized controlled study. Neurorehabilitation and neural repair, 24(1), 42-51.

Lin, K. C., Chung, H. Y., Wu, C. Y., Liu, H. L., Hsieh, Y. W., Chen, I. H., ... & Wai, Y. Y. (2010). Constraint-induced therapy versus control intervention in patients with stroke: a functional magnetic resonance imaging study. American journal of physical medicine & rehabilitation, 89(3), 177-185.

Lin, K. C., Wu, C. Y., Liu, J. S., Chen, Y. T., & Hsu, C. J. (2009). Constraint-induced therapy versus dose-matched control intervention to improve motor ability, basic/extended daily functions, and quality of life in stroke. Neurorehabilitation and Neural Repair, 23(2), 160-165.

Lin, K. C., Wu, C. Y., & Liu, J. S. (2008). A randomized controlled trial of constraint-induced movement therapy after stroke. In Reconstructive Neurosurgery (pp. 61-64). Springer, Vienna.

Lin, K. C., Wu, C. Y., Wei, T. H., Gung, C., Lee, C. Y., & Liu, J. S. (2007). Effects of modified constraint-induced movement therapy on reach-to-grasp movements and functional performance after chronic stroke: a randomized controlled study. *Clinical Rehabilitation*, *21*(12), 1075-1086.

Lin, S. P., Long, Y. M., & Chen, X. H. (2015). The effects of statins on infections after stroke or transient ischemic attack: a meta-analysis. PloS one, 10(7), e0130071.

Lin, Z., & Yan, T. (2011). Long-term effectiveness of neuromuscular electrical stimulation for promoting motor recovery of the upper extremity after stroke. Journal of rehabilitation medicine, 43(6), 506-510.

Lindenberg, R., Renga, V., Zhu, L. L., Nair, D., & Schlaug, G. M. D. P. (2010). Bihemispheric brain stimulation facilitates motor recovery in chronic stroke patients. Neurology, 75(24), 2176-2184.

Linder, S. M., Rosenfeldt, A. B., Bay, R. C., Sahu, K., Wolf, S. L., & Alberts, J. L. (2015). Improving quality of life and depression after stroke through telerehabilitation. American Journal of Occupational Therapy, 69(2), 6902290020p1-6902290020p10.

Liu, K. P., Balderi, K., Leung, T. L. F., Yue, A. S. Y., Lam, N. C. W., Cheung, J. T. Y., ... & Mok, V. C. T. (2016). A randomized controlled trial of self-regulated modified constraint-induced movement therapy in sub-acute stroke patients. European journal of neurology, 23(8), 1351-1360.

Liu, C. H., Hsieh, Y. T., Tseng, H. P., Lin, H. C., Lin, C. L., Wu, T. Y., ... & Zhang, H. (2016). Acupuncture for a first episode of acute ischaemic stroke: an observer-blinded randomised controlled pilot study. Acupuncture in Medicine, 34(5), 349-355.

Liu, H., Song, L. P., & Zhang, T. (2014). Mental practice combined with physical practice to enhance hand recovery in stroke patients. Behavioural neurology, 2014.

Liu, K. P., Chan, C. C., Wong, R. S., Kwan, I. W., Yau, C. S., Li, L. S., & Lee, T. M. (2009). A randomized controlled trial of mental imagery augment generalization of learning in acute poststroke patients. Stroke, 40(6), 2222-2225.

Liu, K. P., Chan, C. C., Lee, T. M., & Hui-Chan, C. W. (2004). Mental imagery for promoting relearning for people after stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 85(9), 1403-1408.

Lo, A. C., Guarino, P. D., Richards, L. G., Haselkorn, J. K., Wittenberg, G. F., Federman, D. G., ... & Bever Jr, C. T. (2010). Robot-assisted therapy for long-term upper-limb impairment after stroke. New England Journal of Medicine, 362(19), 1772-1783.

Lo, Y. L., Cui, S. L., & Fook-Chong, S. (2005). The effect of acupuncture on motor cortex excitability and plasticity. Neuroscience letters, 384(1-2), 145-149.

Long, H., Wang, H., Zhao, C., Duan, Q., Feng, F., Hui, N., ... & Yuan, H. (2018). Effects of combining high-and low-frequency repetitive transcranial magnetic stimulation on upper limb hemiparesis in the early phase of stroke. Restorative neurology and neuroscience, 36(1), 21-30.

Long, H., Wang, H., Zhao, C., Duan, Q., Feng, F., Hui, N., ... & Yuan, H. (2018). Effects of combining high-and low-frequency repetitive transcranial magnetic stimulation on upper limb hemiparesis in the early phase of stroke. Restorative neurology and neuroscience, 36(1), 21-30.

Lüdemann-Podubecká, J., Bösl, K., & Nowak, D. A. (2016). Inhibition of the contralesional dorsal premotor cortex improves motor function of the affected hand following stroke. European journal of neurology, 23(4), 823-830.

Lüdemann-Podubecká, J., Bösl, K., Theilig, S., Wiederer, R., & Nowak, D. A. (2015). The effectiveness of 1Hz rTMS over the primary motor area of the unaffected hemisphere to improve hand function after stroke depends on hemispheric dominance. Brain stimulation, 8(4), 823-830.

Luft, A. R., McCombe-Waller, S., Whitall, J., Forrester, L. W., Macko, R., Sorkin, J. D., ... & Hanley, D. F. (2004). Repetitive bilateral arm training and motor cortex activation in chronic stroke: a randomized controlled trial. Jama, 292(15), 1853-1861.

Lum, P. S., Burgar, C. G., Shor, P. C., Majmundar, M., & Van der Loos, M. (2002). Robot-assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke. Archives of physical medicine and rehabilitation, 83(7), 952-959.

Lum, P., Reinkensmeyer, D., Mahoney, R., Rymer, W. Z., & Burgar, C. (2002). Robotic devices for movement therapy after stroke: current status and challenges to clinical acceptance. Topics in stroke rehabilitation, 8(4), 40-53.

Lynch, D., Ferraro, M., Krol, J., Trudell, C. M., Christos, P., & Volpe, B. T. (2005). Continuous passive motion improves shoulder joint integrity following stroke. Clinical rehabilitation, 19(6), 594-599.

MacIsaac, R. L., Ali, M., Taylor-Rowan, M., Rodgers, H., Lees, K. R., & Quinn, T. J. (2017). Use of a 3-item short-form version of the Barthel Index for use in stroke: systematic review and external validation. Stroke, 48(3), 618-623.

Malcolm, M. P., Triggs, W. J., Light, K. E., Rothi, L. J. G., Wu, S., Reid, K., & Nadeau, S. E. (2007). Repetitive transcranial magnetic stimulation as an adjunct to constraint-induced therapy: an exploratory randomized controlled trial. American journal of physical medicine & rehabilitation/Association of Academic Physiatrists, 86(9), 707.

Malhotra, S., Rosewilliam, S., Hermens, H., Roffe, C., Jones, P., & Pandyan, A. D. (2013). A randomized controlled trial of surface neuromuscular electrical stimulation applied early after acute stroke: effects on wrist pain, spasticity and contractures. Clinical rehabilitation, 27(7), 579-590.

Mann, G. E., Burridge, J. H., Malone, L. J., & Strike, P. W. (2005). A pilot study to investigate the effects of electrical stimulation on recovery of hand function and sensation in subacute stroke patients. Neuromodulation: Technology at the Neural Interface, 8(3), 193-202.

Mangold, S., Schuster, C., Keller, T., Zimmermann-Schlatter, A., & Ettlin, T. (2009). Motor training of upper extremity with functional electrical stimulation in early stroke rehabilitation. Neurorehabilitation and neural repair, 23(2), 184-190.

Mansur, C. G., Fregni, F., Boggio, P. S., Riberto, M., Gallucci-Neto, J., Santos, C. M., ... & Pascual-Leone, A. (2005). A sham stimulation-controlled trial of rTMS of the unaffected hemisphere in stroke patients. Neurology, 64(10), 1802-1804.

Marciniak, C. M., Harvey, R. L., Gagnon, C. M., Duraski, S. A., Denby, F. A., McCarty, S., ... & Fierstein, K. M. (2012). Does botulinum toxin type A decrease pain and lessen disability in hemiplegic survivors of stroke with shoulder pain and spasticity?: a randomized, double-blind,

placebo-controlled trial. American journal of physical medicine & rehabilitation, 91(12), 1007-1019.

Marquez-Chin, C., Bagher, S., Zivanovic, V., & Popovic, M. R. (2017). Functional electrical stimulation therapy for severe hemiplegia: Randomized control trial revisited: La simulation électrique fonctionnelle pour le traitement d'une hémiplégie sévère: un essai clinique aléatoire revisité. Canadian Journal of Occupational Therapy, 84(2), 87-97.

Marquez, J. L., Conley, A. C., Karayanidis, F., Miller, J., Lagopoulos, J., & Parsons, M. W. (2017). Determining the benefits of transcranial direct current stimulation on functional upper limb movement in chronic stroke. International Journal of Rehabilitation Research, 40(2), 138-145.

Marvulli, R., Mastromauro, L., Romanelli, E., Lopopolo, A., Dargenio, M., Fornarelli, F., ... & Ianieri, G. (2016). How botulinum toxin type A-occupational therapy (OT)-functional electrical stimulation (FES) modify spasticity and functional recovery in patients with upper limb spasticity post stroke. Clinical Immunology, Endocrine & Metabolic Drugs, 3(1), 62-67.

Masiero, S., Armani, M., Ferlini, G., Rosati, G., & Rossi, A. (2014). Randomized trial of a robotic assistive device for the upper extremity during early inpatient stroke rehabilitation. Neurorehabilitation and neural repair, 28(4), 377-386.

Masiero, S., Armani, M., & Rosati, G. (2011). Upper-limb robot-assisted therapy in rehabilitation of acute stroke patients: focused review and results of new randomized controlled trial. Journal of Rehabilitation Research & Development, 48(4), 355-367.

Masiero, S., Celia, A., Rosati, G., & Armani, M. (2007). Robotic-assisted rehabilitation of the upper limb after acute stroke. Archives of physical medicine and rehabilitation, 88(2), 142-149.

Masiero, S., Celia, A., Armani, M., & Rosati, G. (2006). A novel robot device in rehabilitation of post-stroke hemiplegic upper limbs. Aging clinical and experimental research, 18(6), 531-535.

Mateen, B. A., Baker, K., & Playford, E. D. (2018). Rasch analysis of the upper-limb subscale of the stroke rehabilitation assessment of movement (STREAM) tool in an acute stroke cohort Rasch analysis of the upper-limb subscale of the STREAM tool in an acute stroke population. Topics in stroke rehabilitation, 1-8.

Mathieson, S., Parsons, J., Kaplan, M., & Parsons, M. (2018). Combining functional electrical stimulation and mirror therapy for upper limb motor recovery following stroke: a randomised trial. European Journal of Physiotherapy, 1-6.

Mazzoleni, S., Battini, E., Crecchi, R., Dario, P., & Posteraro, F. (2018). Upper limb robot-assisted therapy in subacute and chronic stroke patients using an innovative end-effector haptic device: A pilot study. NeuroRehabilitation, 42(1), 43-52.

Mazzoleni, S., Do Tran, V., Iardella, L., Dario, P., & Posteraro, F. (2017, July). Randomized, sham-controlled trial based on transcranial direct current stimulation and wrist robot-assisted integrated treatment on subacute stroke patients: Intermediate results. In 2017 International Conference on Rehabilitation Robotics (ICORR) (pp. 555-560). IEEE.

McCabe, J., Monkiewicz, M., Holcomb, J., Pundik, S., & Daly, J. J. (2015). Comparison of robotics, functional electrical stimulation, and motor learning methods for treatment of persistent

upper extremity dysfunction after stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 96(6), 981-990.

McCombe Waller, S., Whitall, J., Jenkins, T., Magder, L. S., Hanley, D. F., Goldberg, A., & Luft, A. R.(2014). Sequencing bilateral and unilateral task-oriented training versus task oriented training alone to improve arm function in individuals with chronic stroke. BMC Neurology, 14(1), 67-75.

McCombe Waller, S., Liu, W., & Whitall, J. (2008). Temporal and spatial control following bilateral versus unilateral training. Human movement science, 27(5), 749-758.

McDonnell, M. N., Hillier, S. L., Miles, T. S., Thompson, P. D., & Ridding, M. C. (2007). Influence of combined afferent stimulation and task-specific training following stroke: a pilot randomized controlled trial. Neurorehabilitation and neural repair, 21(5), 435-443.

McNulty, P. A., Thompson-Butel, A. G., Faux, S. G., Lin, G., Katrak, P. H., Harris, L. R., & Shiner, C. T. (2015). The efficacy of Wii-based Movement Therapy for upper limb rehabilitation in the chronic poststroke period: a randomized controlled trial. International Journal of Stroke, 10(8), 1253-1260.

Mehrholz, J., Wagner, K., Meissner, D., Grundmann, K., Zange, C., Koch, R., & Pohl, M. (2005). Reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in adult patients with severe brain injury: a comparison study. Clinical rehabilitation, 19(7), 751-759.

Meng, G., Meng, X., Tan, Y., Yu, J., Jin, A., Zhao, Y., & Liu, X. (2018). Short-Term Efficacy of Hand-Arm Bimanual Intensive Training On Upper Arm Function In Acute Stroke Patients: A Randomized Controlled Trial. Frontiers in Neurology, 8, 726.

Meng, Z. Y., & Song, W. Q. (2017). Low frequency repetitive transcranial magnetic stimulation improves motor dysfunction after cerebral infarction. Neural regeneration research, 12(4), 610.

Meythaler, J. M., Vogtle, L., & Brunner, R. C. (2009). A preliminary assessment of the benefits of the addition of botulinum toxin a to a conventional therapy program on the function of people with longstanding stroke. Archives of physical medicine and rehabilitation, 90(9), 1453-1461.

Michielsen, M., Vaughan-Graham, J., Holland, A., Magri, A., & Suzuki, M. (2017). The Bobath concept–a model to illustrate clinical practice. Disability and rehabilitation, 1-13.

Michielsen, M. E., Selles, R. W., van der Geest, J. N., Eckhardt, M., Yavuzer, G., Stam, H. J., ... & Bussmann, J. B. (2011). Motor recovery and cortical reorganization after mirror therapy in chronic stroke patients: a phase II randomized controlled trial. Neurorehabilitation and neural repair, 25(3), 223-233.

Michaelsen, S. M., Dannenbaum, R., & Levin, M. F. (2006). Task-specific training with trunk restraint on arm recovery in stroke: randomized control trial. Stroke, 37(1), 186-192.

Michaelsen, S. M., & Levin, M. F. (2004). Short-term effects of practice with trunk restraint on reaching movements in patients with chronic stroke: a controlled trial. *Stroke*, *35*(8), 1914-1919.

Michimata, A., Kondo, T., Suzukamo, Y., Chiba, M., & Izumi, S. I. (2008). The manual function test: norms for 20-to 90-year-olds and effects of age, gender, and hand dominance on dexterity. The Tohoku journal of experimental medicine, 214(3), 257-267.

Mihara, M., Hattori, N., Hatakenaka, M., Yagura, H., Kawano, T., Hino, T., & Miyai, I. (2013). Near-infrared spectroscopy–mediated neurofeedback enhances efficacy of motor imagery–based training in poststroke victims: a pilot study. Stroke, 44(4), 1091-1098.

Mikami, K., Jorge, R. E., Adams Jr, H. P., Davis, P. H., Leira, E. C., Jang, M., & Robinson, R. G. (2011). Effect of antidepressants on the course of disability following stroke. The American journal of geriatric psychiatry, 19(12), 1007-1015.

Miyamoto, S., Kondo, T., Suzukamo, Y., Michimata, A., & Izumi, S. I. (2009). Reliability and validity of the Manual Function Test in patients with stroke. American journal of physical medicine & rehabilitation, 88(3), 247-255.

Miyasaka, H., Orand, A., Ohnishi, H., Tanino, G., Takeda, K., & Sonoda, S. (2016). Ability of electrical stimulation therapy to improve the effectiveness of robotic training for paretic upper limbs in patients with stroke. Medical engineering & physics, 38(11), 1172-1175.

Mohammadianinejad, S. E., Majdinasab, N., Sajedi, S. A., Abdollahi, F., Moqaddam, M. M., & Sadr, F. (2014). The effect of lithium in post-stroke motor recovery: a double-blind, placebo-controlled, randomized clinical trial. Clinical neuropharmacology, 37(3), 73-78.

Momosaki, R., Yamada, N., Ota, E., & Abo, M. (2017). Repetitive peripheral magnetic stimulation for activities of daily living and functional ability in people after stroke. Cochrane Database of Systematic Reviews, (6).

Monte-Silva (2019). Electromyogram-Related Neuromuscular Electrical Stimulation for Restoring Wrist and Hand Movement in Poststroke Hemiplegia: A Systematic Review and Meta-Analysis.

Moon, S. K., Whang, Y. K., Park, S. U., Ko, C. N., Kim, Y. S., Bae, H. S., & Cho, K. H. (2003). Antispastic effect of electroacupuncture and moxibustion in stroke patients. The American journal of Chinese medicine, 31(03), 467-474.

Morris, J. H., & Van Wijck, F. (2012). Responses of the less affected arm to bilateral upper limb task training in early rehabilitation after stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 93(7), 1129-1137.

Morris, J. H., van Wijck, F., Joice, S., Ogston, S. A., Cole, I., & MacWalter, R. S. (2008). A comparison of bilateral and unilateral upper-limb task training in early poststroke rehabilitation: a randomized controlled trial. Archives of physical medicine and rehabilitation, 89(7), 1237-1245.

Mortensen, J., Figlewski, K., & Andersen, H. (2016). Combined transcranial direct current stimulation and home-based occupational therapy for upper limb motor impairment following intracerebral hemorrhage: a double-blind randomized controlled trial. Disability and rehabilitation, 38(7), 637-643.

Mukherjee, M., McPeak, L. K., Redford, J. B., Sun, C., & Liu, W. (2007). The effect of electro-acupuncture on spasticity of the wrist joint in chronic stroke survivors. *Archives of physical medicine and rehabilitation*, *88*(2), 159-166.

Mulder, M., & Nijland, R. (2016). Stroke Impact Scale. Journal of physiotherapy, 62(2), 117.

Müller, K., Bütefisch, C. M., Seitz, R. J., & Hömberg, V. (2007). Mental practice improves hand function after hemiparetic stroke. Restorative neurology and neuroscience, 25(5, 6), 501-511.

Muresanu, D. F., Heiss, W. D., Hoemberg, V., Bajenaru, O., Popescu, C. D., Vester, J. C., ... & Guekht, A. (2016). Cerebrolysin and Recovery After Stroke (CARS) A randomized, placebo-controlled, double-blind, multicenter trial. Stroke, 47(1), 151-159.

Murphy, M. A., Willén, C., & Sunnerhagen, K. S. (2011). Kinematic variables quantifying upper-extremity performance after stroke during reaching and drinking from a glass. Neurorehabilitation and neural repair, 25(1), 71-80.

Myint, J. M. W. W., Yuen, G. F. C., Yu, T. K. K., Kng, C. P. L., Wong, A. M. Y., Chow, K. K. C., ... & Wong, C. P. (2008). A study of constraint-induced movement therapy in subacute stroke patients in Hong Kong. Clinical rehabilitation, 22(2), 112-124.

Nadeau, S. E., Davis, S. E., Wu, S. S., Dai, Y., & Richards, L. G. (2014). A pilot randomized controlled trial of D-cycloserine and distributed practice as adjuvants to constraint-induced movement therapy after stroke. Neurorehabilitation and Neural Repair, 28(9), 885-895.

Naeser, M. A., Alexander, M. P., Stiassny-Eder, D., Galler, V., Hobbs, J., & Bachman, D. (1992). Real versus sham acupuncture in the treatment of paralysis in acute stroke patients: a CT scan lesion site study. Journal of Neurologic Rehabilitation, 6(4), 163-174.

Naghdi, S., Ansari, N. N., Mansouri, K., & Hasson, S. (2010). A neurophysiological and clinical study of Brunnstrom recovery stages in the upper limb following stroke. Brain injury, 24(11), 1372-1378.

Nam, H. S., Park, Y. G., Paik, N. J., Oh, B. M., Chun, M. H., Yang, H. E., ... & Chang, M. C. (2015). Efficacy and safety of NABOTA in post-stroke upper limb spasticity: a phase 3 multicenter, double-blinded, randomized controlled trial. Journal of the neurological sciences, 357(1-2), 192-197.

Narayan Arya, K., Verma, R., Garg, R. K., Sharma, V. P., Agarwal, M., & Aggarwal, G. G. (2012). Meaningful task-specific training (MTST) for stroke rehabilitation: a randomized controlled trial. Topics in Stroke Rehabilitation, 19(3), 193-211.

Nascimento, L. R., Michaelsen, S. M., Ada, L., Polese, J. C., & Teixeira-Salmela, L. F. (2014). Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review. Journal of physiotherapy, 60(1), 22-30.

Nelson, L. A. (2007). The role of biofeedback in stroke rehabilitation: past and future directions. Topics in stroke rehabilitation, 14(4), 59-66.

Ni, H. H., Cui, X., Hu, Y. S., Wu, Y., Huang, D. Q., Qu, P. Y., ... & Shi, J. C. (2013). Effect of combining acupuncture and functional training on post-stroke functional impairment of hand. Journal of Acupuncture and Tuina Science, 11(6), 349-352.

Nijenhuis, S. M., Prange-Lasonder, G. B., Stienen, A. H., Rietman, J. S., & Buurke, J. H. (2017). Effects of training with a passive hand orthosis and games at home in chronic stroke: a pilot randomised controlled trial. Clinical rehabilitation, 31(2), 207-216.

Nilsson, L., Carlsson, J., Danielsson, A., Fugl-Meyer, A., Hellström, K., Kristensen, L., ... & Grimby, G. (2001). Walking training of patients with hemiparesis at an early stage after stroke: a comparison of walking training on a treadmill with body weight support and walking training on the ground. Clinical Rehabilitation, 15(5), 515-527.

Nomikos, P. A., Spence, N., & Alshehri, M. A. (2018). Test-retest reliability of physiotherapists using the action research arm test in chronic stroke. Journal of Physical Therapy Science, 30(10), 1271-1277.

Ochi, M., Saeki, S., Oda, T., Matsushima, Y., & Hachisuka, K. (2013). Effects of anodal and cathodal transcranial direct current stimulation combined with robotic therapy on severely affected arms in chronic stroke patients. Journal of Rehabilitation Medicine, 45(2), 137-140.

O'Dell, M. W., Kim, G., Rivera, L., Fieo, R., Christos, P., Polistena, C., ... & Gorga, D. (2013). A psychometric evaluation of the Arm Motor Ability Test. *Journal of rehabilitation medicine*, *45*(6), 519-527.

O'Dell, M. W., Kim, G., Finnen, L. R., & Polistena, C. (2011). Clinical implications of using the arm motor ability test in stroke rehabilitation. Archives of physical medicine and rehabilitation, 92(5), 830-836.

Özkeskin, M., Öztürk, V., Çakmur, R., Kara, B., & Küçük, F. (2017). The Effects of Navigated Repetitive Transcranial Magnetic Simulation and Brunnstrom Movement Therapy on Upper Extremity Proprioceptive Sense and Spasticity in Stroke Patients: A Double-Blind Randomized Trial. Journal of Basic and Clinical Health Sciences, 1(2), 29-36.

Ohura, T., Hase, K., Nakajima, Y., & Nakayama, T. (2017). Validity and reliability of a performance evaluation tool based on the modified Barthel Index for stroke patients. BMC medical research methodology, 17(1), 131.

Okuyama, K., Ogura, M., Kawakami, M., Tsujimoto, K., Okada, K., Miwa, K., ... & Liu, M. (2018). Effect of the combination of motor imagery and electrical stimulation on upper extremity motor function in patients with chronic stroke: preliminary results. Therapeutic advances in neurological disorders, 11, 1756286418804785.

Oostra, K. M., Vereecke, A., Jones, K., Vanderstraeten, G., & Vingerhoets, G. (2012). Motor imagery ability in patients with traumatic brain injury. Archives of physical medicine and rehabilitation, 93(5), 828-833.

Osumi, M., Sumitani, M., Otake, Y., & Morioka, S. (2018). A “matched” sensory reference can guide goal-directed movements of the affected hand in central post-stroke sensory ataxia. Experimental brain research, 236(5), 1263-1272.

Lee, M. M., Cho, H. Y., & Song, C. H. (2012). The mirror therapy program enhances upper-limb motor recovery and motor function in acute stroke patients. American journal of physical medicine & rehabilitation, 91(8), 689-700.

Page, S. J. & Peters, H. (2014). Mental practice: applying motor practice and neuroplasticity principles to increase upper extremity function. Stroke, 45(11), 3454-3460.

Page, S. J., Hill, V., & White, S. (2013). Portable upper extremity robotics is as efficacious as upper extremity rehabilitative therapy: a randomized controlled pilot trial. Clinical rehabilitation, 27(6), 494-503.

Page, S. J., Levin, L., Hermann, V., Dunning, K., & Levine, P. (2012). Longer versus shorter daily durations of electrical stimulation during task-specific practice in moderately impaired stroke. Archives of physical medicine and rehabilitation, 93(2), 200-206.

Page, S. J., Dunning, K., Hermann, V., Leonard, A., & Levine, P. (2011). Longer versus shorter mental practice sessions for affected upper extremity movement after stroke: a randomized controlled trial. Clinical rehabilitation, 25(7), 627-637.

Page, S. J., Sisto, S., Levine, P., & McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: a single-blinded randomized controlled trial. Archives of physical medicine and rehabilitation, 85(1), 14-18.

Page, S. J., Levine, P., Leonard, A., Szaflarski, J. P., & Kissela, B. M. (2008). Modified constraint-induced therapy in chronic stroke: results of a single-blinded randomized controlled trial. Physical therapy, 88(3), 333-340.

Page, S. J., Levine, P., & Leonard, A. (2007). Mental practice in chronic stroke: results of a randomized, placebo-controlled trial. Stroke, 38(4), 1293-1297.

Page, S. J., Levine, P., & Leonard, A. C. (2005). Effects of mental practice on affected limb use and function in chronic stroke. Archives of physical medicine and rehabilitation, 86(3), 399-402.

Page, S. J., Levine, P., & Leonard, A. C. (2005). Modified constraint-induced therapy in acute stroke: a randomized controlled pilot study. *Neurorehabilitation and neural repair*, *19*(1), 27-32.

Page, S. J., Sisto, S., Levine, P., & McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: a single-blinded randomized controlled trial. Archives of physical medicine and rehabilitation, 85(1), 14-18.

Page, S. J. (2003). Intensity versus task-specificity after stroke: how important is intensity?. American journal of physical medicine & rehabilitation, 82(9), 730-732.

Page, S. J., Sisto, S., Johnston, M. V., & Levine, P. (2002). Modified constraint-induced therapy after subacute stroke: a preliminary study. Neurorehabilitation and Neural Repair, 16(3), 290-295.

Page, S. J., Levine, P., Sisto, S., & Johnston, M. V. (2001). A randomized efficacy and feasibility study of imagery in acute stroke. *Clinical rehabilitation*, *15*(3), 233-240.

Page, S. J. (2000). Imagery improves upper extremity motor function in chronic stroke patients: a pilot study. The Occupational Therapy Journal of Research, 20(3), 200-215.

Panarese, A., Pirondini, E., Tropea, P., Cesqui, B., Posteraro, F., & Micera, S. (2016). Model-based variables for the kinematic assessment of upper-extremity impairments in post-stroke patients. Journal of neuroengineering and rehabilitation, 13(1), 81.

Pandian, S., Arya, K. N., & Davidson, E. R. (2012). Comparison of Brunnstrom movement therapy and Motor Relearning Program in rehabilitation of post-stroke hemiparetic hand: a randomized trial. Journal of bodywork and movement therapies, 16(3), 330-337.

Pang, M. Y., Eng, J. J., & Miller, W. C. (2007). Determinants of satisfaction with community reintegration in older adults with chronic stroke: role of balance self-efficacy. Physical therapy, 87(3), 282-291.

Pang, M. Y., Harris, J. E., & Eng, J. J. (2006). A community-based upper-extremity group exercise program improves motor function and performance of functional activities in chronic stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 87(1), 1-9.

Pan, L. L. H., Yang, W. W., Kao, C. L., Tsai, M. W., Wei, S. H., Fregni, F., ... & Chou, L. W. (2018). Effects of 8-week sensory electrical stimulation combined with motor training on EEG-EMG coherence and motor function in individuals with stroke. Scientific reports, 8(1), 9217.

Paoloni, M., Tavernese, E., Fini, M., Sale, P., Franceschini, M., Santilli, V., & Mangone, M. (2014). Segmental muscle vibration modifies muscle activation during reaching in chronic stroke: A pilot study. NeuroRehabilitation, 35(3), 405-414.

Papadopoulos, C. M., Tsai, S. Y., Guillen, V., Ortega, J., Kartje, G. L., & Wolf, W. A. (2009). Motor recovery and axonal plasticity with short-term amphetamine after stroke. Stroke, 40(1), 294-302.

Pariente, J., Loubinoux, I., Carel, C., Albucher, J. F., Leger, A., Manelfe, C., ... & Chollet, F. (2001). Fluoxetine modulates motor performance and cerebral activation of patients recovering from stroke. Annals of neurology, 50(6), 718-729.

Park, Chang-Sik (2018). "The test-retest reliability and minimal detectable change of the short-form Barthel Index (5 items) and its associations with chronic stroke-specific impairments." Journal of physical therapy science 30.6, 835-839.

Park, J., Gong, J., & Yim, J. (2017). Effects of a sitting boxing program on upper limb function, balance, gait, and quality of life in stroke patients. NeuroRehabilitation, 40(1), 77-86.

Park, J. S., Choi, J. B., An, D. H., & Chang, M. Y. (2017). Effects of mental practice combined with electromyogram-triggered electrical stimulation for upper extremity function in stroke patients. Journal of physical therapy science, 29(10), 1819-1820.

Park, J. H., & Park, J. H. (2016). The effects of game-based virtual reality movement therapy plus mental practice on upper extremity function in chronic stroke patients with hemiparesis: a randomized controlled trial. Journal of physical therapy science, 28(3), 811-815.

Park, J., Lee, N., Cho, M., Kim, D., & Yang, Y. (2015). Effects of mental practice on stroke patients' upper extremity function and daily activity performance. Journal of physical therapy science, 27(4), 1075-1077.

Park, J. H. (2015). The effects of modified constraint-induced therapy combined with mental practice on patients with chronic stroke. Journal of physical therapy science, 27(5), 1585-1588.

Park, M. H., Jo, S. A., Jo, I., Kim, E., Eun, S. Y., Han, C., & Park, M. K. (2006). No difference in stroke knowledge between Korean adherents to traditional and western medicine–the AGE study: an epidemiological study. BMC Public Health, 6(1), 153.

Park, Y., Chang, M., Kim, K. M., & An, D. H. (2015). The effects of mirror therapy with tasks on upper extremity function and self-care in stroke patients. Journal of physical therapy science, 27(5), 1499-1501.

Park, Y. J., Park, S. W., & Lee, H. S. (2018). Comparison of the effectiveness of whole body vibration in stroke patients: a meta-analysis. BioMed research international, 2018.

Parker, V. M., Wade, D. T., & Hewer, R. L. (1986). Loss of arm function after stroke: measurement, frequency, and recovery. International rehabilitation medicine, 8(2), 69-73.

Patten, C., Condliffe, E. G., Dairaghi, C. A., & Lum, P. S. (2013). Concurrent neuromechanical and functional gains following upper-extremity power training post-stroke. Journal of neuroengineering and rehabilitation, 10(1), 1.

Pavlova, E. L., Lindberg, P., Khan, A., Ruschkowski, S., Nitsche, M. A., & Borg, J. (2017). Transcranial direct current stimulation combined with visuo-motor training as treatment for chronic stroke patients. Restorative neurology and neuroscience, 35(3), 307-317.

Penta, M., Tesio, L., Arnould, C., Zancan, A., & Thonnard, J. L. (2001). The ABILHAND questionnaire as a measure of manual ability in chronic stroke patients: Rasch-based validation and relationship to upper limb impairment. Stroke, 32(7), 1627-1634.

Peterchev, A. V., Wagner, T. A., Miranda, P. C., Nitsche, M. A., Paulus, W., Lisanby, S. H., ... & Bikson, M. (2012). Fundamentals of transcranial electric and magnetic stimulation dose: definition, selection, and reporting practices. Brain stimulation, 5(4), 435-453.

Picelli, A., Lobba, D., Midiri, A., Prandi, P., Melotti, C., Baldessarelli, S., & Smania, N. (2014). Botulinum toxin injection into the forearm muscles for wrist and fingers spastic overactivity in adults with chronic stroke: a randomized controlled trial comparing three injection techniques. Clinical rehabilitation, 28(3), 232-242.

Platz, T., van Kaick, S., Mehrholz, J., Leidner, O., Eickhof, C., & Pohl, M. (2009). Best conventional therapy versus modular impairment-oriented training for arm paresis after stroke: a single-blind, multicenter randomized controlled trial. Neurorehabilitation and neural repair, 23(7), 706-716.

Platz, T., Eickhof, C., Van Kaick, S., Engel, U., Pinkowski, C., Kalok, S., & Pause, M. (2005). Impairment-oriented training or Bobath therapy for severe arm paresis after stroke: a single-blind, multicentre randomized controlled trial. Clinical rehabilitation, 19(7), 714-724.

Platz, T., Pinkowski, C., van Wijck, F., Kim, I. H., Di Bella, P., & Johnson, G. (2005). Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer Test, Action Research Arm Test and Box and Block Test: a multicentre study. Clinical rehabilitation, 19(4), 404-411.

Platz, T., Vuadens, P., Eickhof, C., Arnold, P., Van Kaick, S., & Heise, K. (2008). REPAS, a summary rating scale for resistance to passive movement: item selection, reliability and validity. Disability and rehabilitation, 30(1), 44-53.

Platz, T., Pinkowski, C., van Wijck, F., Kim, I. H., Di Bella, P., & Johnson, G. (2005). Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer Test,

Action Research Arm Test and Box and Block Test: a multicentre study. Clinical rehabilitation, 19(4), 404-411.

Plewnia, C., Hoppe, J., Hiemke, C., Bartels, M., Cohen, L. G., & Gerloff, C. (2002). Enhancement of human cortico-motoneuronal excitability by the selective norepinephrine reuptake inhibitor reboxetine. Neuroscience letters, 330(3), 231-234.

Ploughman, M., & Corbett, D. (2004). Can forced-use therapy be clinically applied after stroke? An exploratory randomized controlled trial. *Archives of physical medicine and rehabilitation*, *85*(9), 1417-1423.

Prange, G. B., Kottink, A. I., Buurke, J. H., Eckhardt, M. M., van Keulen-Rouweler, B. J., Ribbers, G. M., & Rietman, J. S. (2015). The effect of arm support combined with rehabilitation games on upper-extremity function in subacute stroke: a randomized controlled trial. Neurorehabilitation and neural repair, 29(2), 174-182.

Poole, J. L., Whitney, S. L., Hangeland, N., & Baker, C. (1990). The effectiveness of inflatable pressure splints on motor function in stroke patients. The Occupational Therapy Journal of Research, 10(6), 360-366.

Pomeroy, V. M., Cloud, G., Tallis, R. C., Donaldson, C., Nayak, V., & Miller, S. (2007). Transcranial magnetic stimulation and muscle contraction to enhance stroke recovery: a randomized proof-of-principle and feasibility investigation. Neurorehabilitation and neural repair, 21(6), 509-517.

Powell, E. S., Carrico, C., Westgate, P. M., Chelette, K. C., Nichols, L., Reddy, L., ... & Sawaki, L. (2016). Time configuration of combined neuromodulation and motor training after stroke: a proof-of-concept study. NeuroRehabilitation, 39(3), 439-449.

Powell, J., Pandyan, A. D., Granat, M., Cameron, M., & Stott, D. J. (1999). Electrical stimulation of wrist extensors in poststroke hemiplegia. Stroke, 30(7), 1384-1389.

Prange, G. B., Kottink, A. I., Buurke, J. H., Eckhardt, M. M., van Keulen-Rouweler, B. J., Ribbers, G. M., & Rietman, J. S. (2015). The effect of arm support combined with rehabilitation games on upper-extremity function in subacute stroke: a randomized controlled trial. Neurorehabilitation and neural repair, 29(2), 174-182.

Prigatano, G. P., Johnson, S. C., & Gale, S. D. (2004). Neuroimaging correlates of the Halstead Finger Tapping Test several years' post-traumatic brain injury. Brain Injury, 18(7), 661-669.

Qian, Q., Hu, X., Lai, Q., Ng, S. C., Zheng, Y., & Poon, W. (2017). Early stroke rehabilitation of the upper limb assisted with an electromyography-driven neuromuscular electrical stimulation-robotic arm. Frontiers in neurology, 8, 447.

Qian, W., Yu, Z. H. A. O., WANG, C. W., XING, D. B., LÜ, J. Q., Hui, P. A. N., ... & Ning, L. I. (2014). Effects of acupuncture intervention on omalgia incidence rate of ischemic stroke in acute stage. *World Journal of Acupuncture-Moxibustion*, *24*(1), 19-25.

Quinn, T. J., Dawson, J., Walters, M., & Lees, K. R. (2009). Reliability of the modified Rankin Scale: a systematic review. Stroke, 40(10), 3393-3395.

Rabadi, M. H., & Aston, C. E. (2017). Effect of transcranial direct current stimulation on severely affected arm-hand motor function in patients after an acute ischemic stroke: a pilot randomized control trial. American journal of physical medicine & rehabilitation, 96(10), S178-S184.

Rabadi, M. H., Galgano, M., Lynch, D., Akerman, M., Lesser, M., & Volpe, B. T. (2008). A pilot study of activity-based therapy in the arm motor recovery post stroke: a randomized controlled trial. Clinical Rehabilitation, 22(12), 1071-1082.

Rabinstein, A. A., & Shulman, L. M. (2003). Acupuncture in clinical neurology. The neurologist, 9(3), 137-148.

Radajewska, A., Opara, J., Biliński, G., Kaczorowska, A., Nawrat-Szołtysik, A., Kucińska, A., & Lepsy, E. (2016). Effectiveness of mirror therapy for subacute stroke in relation to chosen factors. Rehabilitation Nursing.

Radajewska, A., Opara, J. A., Kucio, C., Blaszczyszyn, M., Mehlich, K., & Szczygiel, J. (2013). The effects of mirror therapy on arm and hand function in subacute stroke in patients. International Journal of Rehabilitation Research, 36(3), 268-274.

Rajesh, T. (2015). Effects of motor imagery on upper extremity functional task performance and quality of life among stroke survivors. Disability, CBR & Inclusive Development, 26(1), 109-124.

Rand, D., Weingarden, H., Weiss, R., Yacoby, A., Reif, S., Malka, R., ... & Zeilig, G. (2017). Self-training to improve UE function at the chronic stage post-stroke: a pilot randomized controlled trial. Disability and rehabilitation, 39(15), 1541-1548.

Reinkensmeyer, D. J., Wolbrecht, E. T., Chan, V., Chou, C., Cramer, S. C., & Bobrow, J. E. (2012). Comparison of 3D, assist-as-needed robotic arm/hand movement training provided with Pneu-WREX to conventional table top therapy following chronic stroke. American journal of physical medicine & rehabilitation/Association of Academic Physiatrists, 91(11 0 3), S232.

Restemeyer, C., Weiller, C., & Liepert, J. (2007). No effect of a levodopa single dose on motor performance and motor excitability in chronic stroke. A double-blind placebo-controlled cross-over pilot study. Restorative neurology and neuroscience, 25(2), 143-150.

Richardson, M., Campbell, N., Allen, L., Meyer, M., & Teasell, R. (2016). The stroke impact scale: Performance as a quality of life measure in a community-based stroke rehabilitation setting. Disability and rehabilitation, 38(14), 1425-1430.

Richards, L., Gonzalez Rothi, L. J., Davis, S., Wu, S. S., & Nadeau, S. E. (2006). Limited dose response to constraint-induced movement therapy in patients with chronic stroke. Clinical rehabilitation, 20(12), 1066-1074.

Riccio, I., Iolascon, G., Barillari, M. R., Gimigliano, R., & Gimigliano, F. (2010). Mental practice is effective in upper limb recovery after stroke: a randomized single-blind cross-over study. European journal of physical and rehabilitation medicine, 46(1), 19-25.

Ring, H., & Rosenthal, N. (2005). Controlled study of neuroprosthetic functional electrical stimulation in sub-acute post-stroke rehabilitation. Journal of rehabilitation medicine, 37(1), 32-36.

Robinson, R. G., Schultz, S. K., Castillo, C., Kopel, T., Kosier, J. T., Newman, R. M., ... & Starkstein, S. E. (2000). Nortriptyline versus fluoxetine in the treatment of depression and in short-term recovery after stroke: a placebo-controlled, double-blind study. American Journal of Psychiatry, 157(3), 351-359.

Rocha, S., Silva, E., Foerster, Á., Wiesiolek, C., Chagas, A. P., Machado, G., ... & Monte-Silva, K. (2016). The impact of transcranial direct current stimulation (tDCS) combined with modified constraint-induced movement therapy (mCIMT) on upper limb function in chronic stroke: a double-blind randomized controlled trial. Disability and rehabilitation, 38(7), 653-660.

Rodrigues, M. R., Slimovitch, M., Chilingaryan, G., & Levin, M. F. (2017). Does the Finger-to-Nose Test measure upper limb coordination in chronic stroke? Journal of neuroengineering and rehabilitation, 14(1), 6.

Rodrigues, L. C., Farias, N. C., Gomes, R. P., & Michaelsen, S. M. (2016). Feasibility and effectiveness of adding object-related bilateral symmetrical training to mirror therapy in chronic stroke: A randomized controlled pilot study. Physiotherapy theory and practice, 32(2), 83-91.

Ro, T., Noser, E., Boake, C., Johnson, R., Gaber, M., Speroni, A., ... & Taub, E. (2006). Functional reorganization and recovery after constraint-induced movement therapy in subacute stroke. Neurocase, 12(1), 50-60.

Roorda, L. D., Houwink, A., Smits, W., Molenaar, I. W., & Geurts, A. C. (2011). Measuring upper limb capacity in poststroke patients: development, fit of the monotone homogeneity model, unidimensionality, fit of the double monotonicity model, differential item functioning, internal consistency, and feasibility of the stroke upper limb capacity scale, SULCS. Archives of physical medicine and rehabilitation, 92(2), 214-227.

Rosales, R., Balcaitiene, J., Berard, H., Maisonobe, P., Goh, K., Kumthornthip, W., ... & Tanvijit, P. (2018). Early AbobotulinumtoxinA (Dysport®) in Post-Stroke Adult Upper Limb Spasticity: ONTIME Pilot Study. Toxins, 10(7), 253.

Rose, D. K., Patten, C., McGuirk, T. E., Lu, X., & Triggs, W. J. (2014). Does inhibitory repetitive transcranial magnetic stimulation augment functional task practice to improve arm recovery in chronic stroke?. Stroke research and treatment, 2014.

Rose, V., & Shah, S. (1987). A comparative study on the immediate effects of hand orthoses on reducation of hypertonus. *Australian occupational therapy journal*, *34*(2), 59-64.

Rösser, N., Heuschmann, P., Wersching, H., Breitenstein, C., Knecht, S., & Flöel, A. (2008). Levodopa improves procedural motor learning in chronic stroke patients. Archives of physical medicine and rehabilitation, 89(9), 1633-1641.

Rowe, J. B., Chan, V., Ingemanson, M. L., Cramer, S. C., Wolbrecht, E. T., & Reinkensmeyer, D. J. (2017). Robotic assistance for training finger movement using a Hebbian model: a randomized controlled trial. Neurorehabilitation and neural repair, 31(8), 769-780.

Safaz, I., Ylmaz, B., Yasar, E., & Alaca, R. (2009). Brunnstrom recovery stage and motricity index for the evaluation of upper extremity in stroke: analysis for correlation and responsiveness. International Journal of Rehabilitation Research, 32(3), 228-231.

Sahin, N., Ugurlu, H., & Albayrak, I. (2012). The efficacy of electrical stimulation in reducing the post-stroke spasticity: a randomized controlled study. Disability and rehabilitation, 34(2), 151-156.

Sahin, F., Yilmaz, F., Ozmaden, A., Kotevoglu, N., Sahin, T., & Kuran, B. (2008). Reliability and validity of the Turkish version of the Nottingham Extended Activities of Daily Living Scale. Aging clinical and experimental research, 20(5), 400-405.

Salaffi, F., Di Carlo, M., Carotti, M., & Farah, S. (2018). Validity and interpretability of the QuickDASH in the assessment of hand disability in rheumatoid arthritis. Rheumatology international, 1-10.

Sale, P., Ceravolo, M. G., & Franceschini, M. (2014). Action observation therapy in the subacute phase promotes dexterity recovery in right-hemisphere stroke patients. BioMed research international, 2014.

Sale, P., Franceschini, M., Mazzoleni, S., Palma, E., Agosti, M., & Posteraro, F. (2014). Effects of upper limb robot-assisted therapy on motor recovery in subacute stroke patients. Journal of neuroengineering and rehabilitation, 11(1), 104.

Sale, P., Mazzoleni, S., Lombardi, V., Galafate, D., Massimiani, M. P., Posteraro, F., ... & Franceschini, M. (2014). Recovery of hand function with robot-assisted therapy in acute stroke patients: a randomized-controlled trial. International journal of rehabilitation research, 37(3), 236-242.

Sallés, L., Martín-Casas, P., Gironès, X., Durà, M. J., Lafuente, J. V., & Perfetti, C. (2017). A neurocognitive approach for recovering upper extremity movement following subacute stroke: a randomized controlled pilot study. Journal of physical therapy science, 29(4), 665-672.

Samuelkamaleshkumar, S., Reethajanetsureka, S., Pauljebaraj, P., Benshamir, B., Padankatti, S. M., & David, J. A. (2014). Mirror therapy enhances motor performance in the paretic upper limb after stroke: a pilot randomized controlled trial. Archives of physical medicine and rehabilitation, 95(11), 2000-2005.ized clinical trial. Indian Journal of Physiotherapy & Occupational Therapy, 10(1), 71-75.

Sanford, J., Moreland, J., Swanson, L. R., Stratford, P. W., & Gowland, C. (1993). Reliability of the Fugl-Meyer assessment for testing motor performance in patients following stroke. Physical therapy, 73(7), 447-454.

Santamato, A., Micello, M. F., Panza, F., Fortunato, F., Picelli, A., Smania, N., ... & Ranieri, M. (2015). Adhesive taping vs. daily manual muscle stretching and splinting after botulinum toxin type A injection for wrist and fingers spastic overactivity in stroke patients: a randomized controlled trial. Clinical rehabilitation, 29(1), 50-58.

Santamato, A., Micello, M. F., Panza, F., Fortunato, F., Baricich, A., Cisari, C., ... & Ranieri, M. (2014). Can botulinum toxin type A injection technique influence the clinical outcome of patients with post-stroke upper limb spasticity? A randomized controlled trial comparing manual needle placement and ultrasound-guided injection techniques. Journal of the neurological sciences, 347(1-2), 39-43.

Santamato, A., Notarnicola, A., Panza, F., Ranieri, M., Micello, M. F., Manganotti, P., ... & Fiore, P. (2013). SBOTE study: extracorporeal shock wave therapy versus electrical stimulation after botulinum toxin type a injection for post-stroke spasticity–a prospective randomized trial. Ultrasound in medicine & biology, 39(2), 283-291.

Saposnik, G., Cohen, L. G., Mamdani, M., Pooyania, S., Ploughman, M., Cheung, D., ... & Nilanont, Y. (2016). Efficacy and safety of non-immersive virtual reality exercising in stroke rehabilitation (EVREST): a randomised, multicentre, single-blind, controlled trial. The Lancet Neurology, 15(10), 1019-1027.

Saposnik, G., Teasell, R., Mamdani, M., Hall, J., McIlroy, W., Cheung, D., ... & Bayley, M. (2010). Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. Stroke, 41(7), 1477-1484.

Sasaki, N., Mizutani, S., Kakuda, W., & Abo, M. (2013). Comparison of the effects of high-and low-frequency repetitive transcranial magnetic stimulation on upper limb hemiparesis in the early phase of stroke. Journal of stroke and cerebrovascular diseases, 22(4), 413-418.

Sattler, V., Acket, B., Raposo, N., Albucher, J. F., Thalamas, C., Loubinoux, I., ... & Simonetta-Moreau, M. (2015). Anodal tDCS combined with radial nerve stimulation promotes hand motor recovery in the acute phase after ischemic stroke. Neurorehabilitation and neural repair, 29(8), 743-754.

Sawaki, L., Butler, A. J., Leng, X., Wassenaar, P. A., Mohammad, Y. M., Blanton, S., ... & Wittenberg, G. F. (2008). Constraint-induced movement therapy results in increased motor map area in subjects 3 to 9 months after stroke. *Neurorehabilitation and neural repair*, *22*(5), 505-513.

Schick, T., Schlake, H. P., Kallusky, J., Hohlfeld, G., Steinmetz, M., Tripp, F., ... & Dohle, C. (2017). Synergy effects of combined multichannel EMG-triggered electrical stimulation and mirror therapy in subacute stroke patients with severe or very severe arm/hand paresis. Restorative neurology and neuroscience, 35(3), 319-332.

Scholz, D. S., Rohde, S., Nikmaram, N., Brückner, H. P., Großbach, M., Rollnik, J. D., & Altenmüller, E. O. (2016). Sonification of arm movements in stroke rehabilitation–a novel approach in neurologic music therapy. Frontiers in neurology, 7, 106.

Schwippel, T., Schroeder, P. A., Fallgatter, A. J., & Plewnia, C. (2019). Clinical review: The therapeutic use of theta-burst stimulation in mental disorders and tinnitus. Progress in Neuro-Psychopharmacology and Biological Psychiatry.

Schuling, J., De Haan, R., Limburg, M. T., & Groenier, K. H. (1993). The Frenchay Activities Index. Assessment of functional status in stroke patients. Stroke, 24(8), 1173-1177.

Schuster-Amft, C., Eng, K., Suica, Z., Thaler, I., Signer, S., Lehmann, I., ... & Kiper, D. (2018). Effect of a four-week virtual reality-based training versus conventional therapy on upper limb motor function after stroke: A multicenter parallel group randomized trial. PloS one, 13(10), e0204455.

Schuster, C., Maunz, G., Lutz, K., Kischka, U., Sturzenegger, R., & Ettlin, T. (2011). Dexamphetamine improves upper extremity outcome during rehabilitation after stroke: a pilot randomized controlled trial. Neurorehabilitation and neural repair, 25(8), 749-755.

Seki, M., Hase, K., Takahashi, H., & Liu, M. (2014). Comparison of three instruments to assess changes of motor impairment

Seniów, J., Bilik, M., Leśniak, M., Waldowski, K., Iwański, S., & Członkowska, A. (2012). Transcranial magnetic stimulation combined with physiotherapy in rehabilitation of poststroke hemiparesis: a randomized, double-blind, placebo-controlled study. Neurorehabilitation and neural repair, 26(9), 1072-1079.

Seok, H., Lee, S. Y., Kim, J., Yeo, J., & Kang, H. (2016). Can short-term constraint-induced movement therapy combined with visual biofeedback training improve hemiplegic upper limb function of subacute stroke patients?. *Annals of rehabilitation medicine*, *40*(6), 998.

Seo, H. G., Paik, N. J., Lee, S. U., Oh, B. M., Chun, M. H., Kwon, B. S., & Bang, M. S. (2015). Neuronox versus BOTOX in the treatment of post-stroke upper limb spasticity: a multicenter randomized controlled trial. PloS one, 10(6), e0128633.

Sezer, N., Yavuzer, G., Sivrioglu, K., Basaran, P., & Koseoglu, B. F. (2007). Clinimetric properties of the Duruoz hand index in patients with stroke. Archives of physical medicine and rehabilitation, 88(3), 309-314.

Shah, M. V., Kumar, S., & Muragod, A. R. (2016). Effect of constraint induced movement therapy v/s motor relearning program for upper extremity function in sub acute hemiparetic patients-a random

Shaheiwola, N., Zhang, B., Jia, J., & Zhang, D. (2018). Using tDCS as an add-on treatment prior to FES therapy in improving upper limb function in severe chronic stroke patients: A randomized controlled study. Frontiers in human neuroscience, 12.

Shaw, L. C., Price, C. I., van Wijck, F. M., Shackley, P., Steen, N., Barnes, M. P., ... & Rodgers, H. (2011). Botulinum Toxin for the Upper Limb after Stroke (BoTULS) Trial: effect on impairment, activity limitation, and pain. Stroke, 42(5), 1371-1379.

Shaw, L., Rodgers, H., Price, C., van Wijck, F., Shackley, P., Steen, N., ... & Graham, L. (2010). BoTULS: a multicentre randomised controlled trial to evaluate the clinical effectiveness and cost-effectiveness of treating upper limb spasticity due to stroke with botulinum toxin type A. Health Technol Assess, 14(26), 1-113.

Shim, S., & Jung, J. (2015). Effects of bilateral training on motor function, amount of activity and activity intensity measured with an accelerometer of patients with stroke. Journal of Physical Therapy Science, 27(3), 751-754.

Shimodozono, M., Noma, T., Nomoto, Y., Hisamatsu, N., Kamada, K., Miyata, R., ... & Kawahira, K. (2013). Benefits of a repetitive facilitative exercise program for the upper paretic extremity after subacute stroke: A randomized controlled trial. Neurorehabilitation and neural repair, 27(4), 296-305.

Shimodozono, M., Noma, T., Matsumoto, S., Miyata, R., Etoh, S., & Kawahira, K. (2014). Repetitive facilitative exercise under continuous electrical stimulation for severe arm impairment after sub-acute stroke: a randomized controlled pilot study. Brain injury, 28(2), 203-210.

Shin, J. H., Kim, M. Y., Lee, J. Y., Jeon, Y. J., Kim, S., Lee, S., ... & Choi, Y. (2016). Effects of virtual reality-based rehabilitation on distal upper extremity function and health-related quality of life: a single-blinded, randomized controlled trial. Journal of neuroengineering and rehabilitation, 13(1), 17.

Shin, J. H., Park, S. B., & Jang, S. H. (2015). Effects of game-based virtual reality on health-related quality of life in chronic stroke patients: A randomized, controlled study. Computers in biology and medicine, 63, 92-98.

Shindo, K., Fujiwara, T., Hara, J., Oba, H., Hotta, F., Tsuji, T., ... & Liu, M. (2011). Effectiveness of hybrid assistive neuromuscular dynamic stimulation therapy in patients with subacute stroke: a randomized controlled pilot trial. Neurorehabilitation and neural repair, 25(9), 830-837.

Sicuri, C., Porcellini, G., & Merolla, G. (2014). Robotics in shoulder rehabilitation. Muscles, ligaments and tendons journal, 4(2), 207.

Şik, B. Y., Dursun, N., Dursun, E., Sade, I., & Şahin, E. (2015). Transcranial Direct Current Stimulation: The Effects On Plegic Upper Extremity Motor Function of Patients With Stroke. Journal of Neurological Sciences, 32(2).

Simondson, J. A., Goldie, P., & Greenwood, K. M. (2003). The mobility scale for acute stroke patients: concurrent validity. Clinical rehabilitation, 17(5), 558-564.

Simpson, D. M., Alexander, D. N., O'brien, C. F., Tagliati, M., Aswad, A. S., Leon, J. M., ... & Monaghan, E. P. (1996). Botulinum toxin type A in the treatment of upper extremity spasticity: a randomized, double-blind, placebo-controlled trial. Neurology, 46(5), 1306-1306.

Simpson, D. M., Gracies, J. M., Yablon, S. A., Barbano, R., Brashear, A., & BoNT/TZD Study Team. (2009). Botulinum neurotoxin versus tizanidine in upper limb spasticity: a placebo-controlled study. Journal of Neurology, Neurosurgery & Psychiatry, 80(4), 380-385.

Singer, B. J., Vallence, A. M., Cleary, S., Cooper, I., & Loftus, A. M. (2013). The effect of EMG triggered electrical stimulation plus task practice on arm function in chronic stroke patients with moderate-severe arm deficits. Restorative neurology and neuroscience, 31(6), 681-691.

Singh, H. P., Dias, J. J., & Thompson, J. R. (2015). Timed Sollerman hand function test for analysis of hand function in normal volunteers. Journal of Hand Surgery (European Volume), 40(3), 298-309.

Sin, H., & Lee, G. (2013). Additional virtual reality training using Xbox Kinect in stroke survivors with hemiplegia. American journal of physical medicine & rehabilitation, 92(10), 871-880.

Skubik-Peplaski, C., Custer, M., Powell, E., Westgate, P. M., & Sawaki, L. (2017). Comparing occupation-based and repetitive task practice interventions for optimal stroke recovery: a pilot randomized trial. Physical & Occupational Therapy In Geriatrics, 35(3-4), 156-168.

Smania, N., Gandolfi, M., Paolucci, S., Iosa, M., Ianes, P., Recchia, S., ... & Zaccala, M. (2012). Reduced-intensity modified constraint-induced movement therapy versus conventional therapy

for upper extremity rehabilitation after stroke: a multicenter trial. Neurorehabilitation and neural repair, 26(9), 1035-1045.

Smith, S. J., Ellis, E., White, S., & Moore, A. P. (2000). A double-blind placebo-controlled study of botulinum toxin in upper limb spasticity after stroke or head injury. Clinical rehabilitation, 14(1), 5-13.

Snow, B. J., Tsui, J. K., Bhatt, M. H., Varelas, M., Hashimoto, S. A., & Calne, D. B. (1990). Treatment of spasticity with botulinum toxin: a double-blind study. Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society, 28(4), 512-515.

Sonde, L., Fernaeus, S. E., Nilsson, C. G., & Viitanen, M. (1998). Stimulation With Low Frequency (1.7 Hz) Transcutaneous Electric Nerve Stimulation (Low-Tens) Increases Motor. Scand J Rehab Med, 30, 95-99.

Song, G. B. (2015). The effects of task-oriented versus repetitive bilateral arm training on upper limb function and activities of daily living in stroke patients. Journal of physical therapy science, 27(5), 1353-1355.

Song, Y., Kang, L., Dong, H., & Chen, Y. (2016). Combined rehabilitation with scalp cluster acupuncture and constraint-induced movement therapy significantly improved functional recovery in patients with acute ischemic stroke. International Journal of Clinical and Experimental Medicine, 9(10), 19797-19802.

Song, Y., Kang, L., Dong, H., & Chen, Y. (2016). Combined rehabilitation with scalp cluster acupuncture and constraint-induced movement therapy significantly improved functional recovery in patients with acute ischemic stroke. International Journal of Clinical and Experimental Medicine, 9(10), 19797-19802.

Souza, W. C., Conforto, A. B., Orsini, M., Stern, A., & André, C. (2015). Similar effects of two modified constraint-induced therapy protocols on motor impairment, motor function and quality of life in patients with chronic stroke. Neurology international, 7(1).

Stagg, C. J., Bachtiar, V., O'shea, J., Allman, C., Bosnell, R. A., Kischka, U., ... & Johansen-Berg, H. (2011). Cortical activation changes underlying stimulation-induced behavioural gains in chronic stroke. Brain, 135(1), 276-284.

Standen, P. J., Threapleton, K., Richardson, A., Connell, L., Brown, D. J., Battersby, S., ... & Burton, A. (2017). A low cost virtual reality system for home based rehabilitation of the arm following stroke: a randomised controlled feasibility trial. Clinical rehabilitation, 31(3), 340-350.

Stefanovic, A., & Schwirtlich, L. (2003). Clinical evaluation of functional electrical therapy in acute hemiplegic subjects. Journal of rehabilitation research and development, 40(5), 443-454.

Stein, J., Hughes, R., D'Andrea, S., Therrien, B., Niemi, J., Krebs, K., ... & Harry, J. (2010). Stochastic resonance stimulation for upper limb rehabilitation poststroke. American journal of physical medicine & rehabilitation, 89(9), 697-705.

Stein, J., Krebs, H. I., Frontera, W. R., Fasoli, S. E., Hughes, R., & Hogan, N. (2004). Comparison of two techniques of robot-aided upper limb exercise training after stroke. American journal of physical medicine & rehabilitation, 83(9), 720-728.

Stern, E. B. (1992). Stability of the Jebsen-Taylor Hand Function Test across three test sessions. American journal of occupational therapy, 46(7), 647-649.

Stewart, K. C., Cauraugh, J. H., & Summers, J. J. (2006). Bilateral movement training and stroke rehabilitation: a systematic review and meta-analysis. Journal of the neurological sciences, 244(1-2), 89-95.

Stinear, C. M., Petoe, M. A., Anwar, S., Barber, P. A., & Byblow, W. D. (2014). Bilateral Priming Accelerates Recovery of Upper Limb Function After Stroke A Randomized Controlled Trial. Stroke, 45(1), 205-210.

Stinear, C. M., Barber, P. A., Coxon, J. P., Fleming, M. K., & Byblow, W. D. (2008). Priming the motor system enhances the effects of upper limb therapy in chronic stroke. Brain, 131(Pt 5), 1381-1390.

Stoykov, M. E., Lewis, G. N., & Corcos, D. M. (2009). Comparison of bilateral and unilateral training for upper extremity hemiparesis in stroke. Neurorehabil Neural Repair., 23(9), 945-953.

Straudi, S., Fregni, F., Martinuzzi, C., Pavarelli, C., Salvioli, S., & Basaglia, N. (2016). tDCS and robotics on upper limb stroke rehabilitation: effect modification by stroke duration and type of stroke. BioMed research international, 2016.

Sturma, A., Hruby, L. A., Prahm, C., Mayer, J. A., & Aszmann, O. C. (2018). Rehabilitation of upper extremity nerve injuries using surface EMG biofeedback: Protocols for clinical application. Frontiers in neuroscience, 12, 906.

Summers, J. J., Kagerer, F. A., Garry, M. I., Hiraga, C. Y., Loftus, A., & Cauraugh, J. H. (2007). Bilateral and unilateral movement training on upper limb function in chronic stroke patients: a TMS study. Journal of the neurological sciences, 252(1), 76-82.

Sunderland, A., Tinson, D., Bradley, L., & Hewer, R. L. (1989). Arm function after stroke. An evaluation of grip strength as a measure of recovery and a prognostic indicator. Journal of Neurology, Neurosurgery & Psychiatry, 52(11), 1267-1272.

Sung, W. H., Wang, C. P., Chou, C. L., Chen, Y. C., Chang, Y. C., & Tsai, P. Y. (2013). Efficacy of coupling inhibitory and facilitatory repetitive transcranial magnetic stimulation to enhance motor recovery in hemiplegic stroke patients. Stroke, 44(5), 1375-1382.

Sun, S. F., Hsu, C. W., Sun, H. P., Hwang, C. W., Yang, C. L., & Wang, J. L. (2010). Combined botulinum toxin type A with modified constraint-induced movement therapy for chronic stroke patients with upper extremity spasticity: a randomized controlled study. Neurorehabilitation and neural repair, 24(1), 34-41.

Suputtitada, A., & Suwanwela, N. C. (2005). The lowest effective dose of botulinum A toxin in adult patients with upper limb spasticity. Disability and rehabilitation, 27(4), 176-184.

Suputtitada, A., Suwanwela, N. C., & Tumvitee, S. (2004). Effectiveness of constraint-induced movement therapy in chronic stroke patients. J Med Assoc Thai, 87(12), 1482-90.

Surrey, L. R., Nelson, K., Delelio, C., Mathie-Majors, D., Omel-Edwards, N., Shumaker, J., & Thurber, G. (2003). A comparison of performance outcomes between the Minnesota Rate of Manipulation Test and the Minnesota Manual Dexterity Test. Work, 20(2), 97-102.

Susanto, E. A., Tong, R. K., Ockenfeld, C., & Ho, N. S. (2015). Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial. Journal of neuroengineering and rehabilitation, 12(1), 42.

Sze, F. K. H., Wong, E., Yi, X., & Woo, J. (2002). Does acupuncture have additional value to standard poststroke motor rehabilitation?. Stroke, 33(1), 186-194.

Takebayashi, T., Koyama, T., Amano, S., Hanada, K., Tabusadani, M., Hosomi, M., ... & Domen, K. (2013). A 6-month follow-up after constraint-induced movement therapy with and without transfer package for patients with hemiparesis after stroke: a pilot quasi-randomized controlled trial. Clinical rehabilitation, 27(5), 418-426.

Takeuchi, N., Tada, T., Toshima, M., Matsuo, Y., & Ikoma, K. (2009). Repetitive transcranial magnetic stimulation over bilateral hemispheres enhances motor function and training effect of paretic hand in patients after stroke. Journal of rehabilitation medicine, 41(13), 1049-1054.

Takeuchi, N., Chuma, T., Matsuo, Y., Watanabe, I., & Ikoma, K. (2005). Repetitive transcranial magnetic stimulation of contralesional primary motor cortex improves hand function after stroke. Stroke, 36(12), 2681-2686.

Talelli, P., Wallace, A., Dileone, M., Hoad, D., Cheeran, B., Oliver, R., ... & Musumeci, G. (2012). Theta burst stimulation in the rehabilitation of the upper limb: a semirandomized, placebo-controlled trial in chronic stroke patients. Neurorehabilitation and neural repair, 26(8), 976-987.

Tambasco, N., Romoli, M., & Calabresi, P. (2018). Levodopa in Parkinson's disease: current status and future developments. Current neuropharmacology, 16(8), 1239-1252.

Tardy, J., Pariente, J., Leger, A., Dechaumont-Palacin, S., Gerdelat, A., Guiraud, V., ... & Cognard, C. (2006). Methylphenidate modulates cerebral post-stroke reorganization. Neuroimage, 33(3), 913-922.

Tarri, M., Brimhat, N., Gasq, D., Lepage, B., Loubinoux, I., De Boissezon, X., ... & Castel-Lacanal, E. (2018). Five-day course of paired associative stimulation fails to improve motor function in stroke patients. Annals of physical and rehabilitation medicine, 61(2), 78-84.

Taub, E., Uswatte, G., Mark, V. W., Morris, D. M., Barman, J., Bowman, M. H., ... & Bishop-McKay, S. (2013). Method for enhancing real-world use of a more affected arm in chronic stroke: transfer package of constraint-induced movement therapy. Stroke, 44(5), 1383-1388.

Takebayashi, T., Takahashi, K., Moriwaki, M., Sakamoto, T., & Domen, K. (2017). Improvement of upper extremity deficit after constraint-induced movement therapy combined with and without preconditioning stimulation using dual-hemisphere transcranial direct current stimulation and peripheral neuromuscular stimulation in chronic stroke patients: A pilot randomized controlled trial. Frontiers in neurology, 8, 568.

Takeuchi, N., Tada, T., Toshima, M., Chuma, T., Matsuo, Y., & Ikoma, K. (2008). Inhibition of the unaffected motor cortex by 1 Hz repetitive transcranial magnetic stimulation enhances motor performance and training effect of the paretic hand in patients with chronic stroke. Journal of Rehabilitation Medicine, 40(4), 298-303.

Tanaka, S., Takeda, K., Otaka, Y., Kita, K., Osu, R., Honda, M., ... & Watanabe, K. (2011). Single session of transcranial direct current stimulation transiently increases knee extensor force in patients with hemiparetic stroke. Neurorehabilitation and neural repair, 25(6), 565-569.

Tavernese, E., Paoloni, M., Mangone, M., Mandic, V., Sale, P., Franceschini, M., & Santilli, V. (2013). Segmental muscle vibration improves reaching movement in patients with chronic stroke. A randomized controlled trial. NeuroRehabilitation, 32(3), 591-599.

Tekeolu, Y. B., Adak, B., & Göksoy, T. (1998). Effect of transcutaneous electrical nerve stimulation (TENS) on Barthel Activities of Daily Living (ADL) index score following stroke. Clinical rehabilitation, 12(4), 277-280.

Teoli D, An J. Transcutaneous Electrical Nerve Stimulation (TENS) [Updated 2019 Jan 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2018 Jan-. Available from: https://www-ncbi-nlm-nih-gov.proxy1.lib.uwo.ca/books/NBK537188

Thanakiatpinyo, T., Suwannatrai, S., Suwannatrai, U., Khumkaew, P., Wiwattamongkol, D., Vannabhum, M., ... & Kuptniratsaikul, V. (2014). The efficacy of traditional Thai massage in decreasing spasticity in elderly stroke patients. Clinical interventions in aging, 9, 1311.

Thibaut, A., Chatelle, C., Ziegler, E., Bruno, M. A., Laureys, S., & Gosseries, O. (2013). Spasticity after stroke: physiology, assessment and treatment. Brain injury, 27(10), 1093-1105.

Thielbar, K. O., Lord, T. J., Fischer, H. C., Lazzaro, E. C., Barth, K. C., Stoykov, M. E., ... & Kamper, D. G. (2014). Training finger individuation with a mechatronic-virtual reality system leads to improved fine motor control post-stroke. Journal of neuroengineering and rehabilitation, 11(1), 171.

Thanakiatpinyo, T., Suwannatrai, S., Suwannatrai, U., Khumkaew, P., Wiwattamongkol, D., Vannabhum, M., ... & Kuptniratsaikul, V. (2014). The efficacy of traditional Thai massage in decreasing spasticity in elderly stroke patients. Clinical interventions in aging, 9, 1311.

Thielman, G. (2013). Insights into upper limb kinematics and trunk control one year after task-related training in chronic post-stroke individuals. Journal of Hand Therapy, 26(2), 156-161.

Thielman, G., & Bonsall, P. (2012). Rehabilitation of the upper extremity after stroke: a case series evaluating REO therapy and an auditory sensor feedback for trunk control. Stroke research and treatment, 2012.

Thielman, G. (2010). Rehabilitation of reaching poststroke: a randomized pilot investigation of tactile versus auditory feedback for trunk control. Journal of Neurologic Physical Therapy, 34(3), 138-144.

Thielman, G. T., Dean, C. M., & Gentile, A. M. (2004). Rehabilitation of reaching after stroke: task-related training versus progressive resistive exercise. Archives of physical medicine and rehabilitation, 85(10), 1613-1618.

Thieme, H., Bayn, M., Wurg, M., Zange, C., Pohl, M., & Behrens, J. (2013). Mirror therapy for patients with severe arm paresis after stroke–a randomized controlled trial. Clinical rehabilitation, 27(4), 314-324.

Thompson-Butel, A. G., Lin, G. G., Shiner, C. T., & McNulty, P. A. (2014). Two common tests of dexterity can stratify upper limb motor function after stroke. Neurorehabilitation and neural repair, 28(8), 788-796.

Thrane, G., Askim, T., Stock, R., Indredavik, B., Gjone, R., Erichsen, A., & Anke, A. (2015). Efficacy of constraint-induced movement therapy in early stroke rehabilitation: a randomized controlled multisite trial. Neurorehabilitation and neural repair, 29(6), 517-525.

Thrasher, T. A., Zivanovic, V., McIlroy, W., & Popovic, M. R. (2008). Rehabilitation of reaching and grasping function in severe hemiplegic patients using functional electrical stimulation therapy. Neurorehabilitation and neural repair, 22(6), 706-714.

Tilkici, M., Alemdaroglu, E., Mandiroglu, S., Ordu Gokkaya N., Ucan, H., Aykan, S. (2017). The Effect of Upper Extremity Electrical Stimulation in Addition to Conventional Rehabilitation in Individuals with Chronic Stroke: Randomized Controlled Study. Journal of physical medicine and rehabilitation sciences, 20(3), 126-133.

Timmermans, A. A., Verbunt, J. A., van Woerden, R., Moennekens, M., Pernot, D. H., & Seelen, H. A. (2013). Effect of mental practice on the improvement of function and daily activity performance of the upper extremity in patients with subacute stroke: a randomized clinical trial. Journal of the American Medical Directors Association, 14(3), 204-212.

Timmermans, A. A., Lemmens, R. J., Monfrance, M., Geers, R. P., Bakx, W., Smeets, R. J., & Seelen, H. A. (2014). Effects of task-oriented robot training on arm function, activity, and quality of life in chronic stroke patients: a randomized controlled trial. Journal of neuroengineering and rehabilitation, 11(1), 45.

Tomić, T. J. D., Savić, A. M., Vidaković, A. S., Rodić, S. Z., Isaković, M. S., Rodríguez-de-Pablo, C., ... & Konstantinović, L. M. (2017). ArmAssist robotic system versus matched conventional therapy for poststroke upper limb rehabilitation: a randomized clinical trial. BioMed research international, 2017.

Tomljanović, M., Spasić, M., Gabrilo, G., Uljević, O., & Foretić, N. (2011). Effects of five weeks of functional vs. traditional resistance training on anthropometric and motor performance variables. Kinesiology: International journal of fundamental and applied kinesiology, 43(2), 145-154.

Tong, Y., Forreider, B., Sun, X., Geng, X., Zhang, W., Du, H., ... & Ding, Y. (2015). Music-supported therapy (MST) in improving post-stroke patients' upper-limb motor function: a randomised controlled pilot study. Neurological research, 37(5), 434-440.

Tosun, A., Türe, S., Askin, A., Yardimci, E. U., Demirdal, S. U., Kurt Incesu, T., ... & Gelal, F. M. (2017). Effects of low-frequency repetitive transcranial magnetic stimulation and neuromuscular electrical stimulation on upper extremity motor recovery in the early period after stroke: a preliminary study. Topics in stroke rehabilitation, 24(5), 361-367.

Treger, I., Aidinof, L., Lehrer, H., & Kalichman, L. (2012). Modified constraint-induced movement therapy improved upper limb function in subacute poststroke patients: a small-scale clinical trial. Topics in stroke rehabilitation, 19(4), 287-293.

Triccas, L. T., Burridge, J. H., Hughes, A., Verheyden, G., Desikan, M., & Rothwell, J. (2015). A double-blinded randomised controlled trial exploring the effect of anodal transcranial direct current stimulation and uni-lateral robot therapy for the impaired upper limb in sub-acute and chronic stroke. NeuroRehabilitation, 37(2), 181-191.

Trombly, C. A., Thayer-Nason, L., Bliss, G., Girard, C. A., Lyrist, L. A., & Brexa-Hooson, A. (1986). The effectiveness of therapy in improving finger extension in stroke patients. American Journal of Occupational Therapy, 40(9), 612-617.

Tseng, C. N., Chen, C. C. H., Wu, S. C., & Lin, L. C. (2007). Effects of a range-of-motion exercise programme. Journal of Advanced Nursing, 57(2), 181-191.

Tsubokawa, T., Katayama, Y., Yamamoto, T., Hirayama, T., & Koyama, S. (1991). Treatment of thalamic pain by chronic motor cortex stimulation. Pacing and Clinical Electrophysiology, 14(1), 131-134.

Türkbey, T. A., Kutlay, Ş., & Gök, H. (2017). Clinical feasibility of Xbox KinectTM training for stroke rehabilitation: a single-blind randomized controlled pilot study. Journal of rehabilitation medicine, 49(1), 22-29.

Umar, M., Masood, T., & Badshah, M. (2018). Effect of botulinum toxin A & task-specific training on upper limb function in post-stroke focal dystonia. JPMA. The Journal of the Pakistan Medical Association, 68(4), 526-531.

Underwood, J., Clark, P. C., Blanton, S., Aycock, D. M., & Wolf, S. L. (2006). Pain, fatigue, and intensity of practice in people with stroke who are receiving constraint-induced movement therapy. Physical therapy, 86(9), 1241-1250.

Valles, K. B., Montes, S., de Jesus Madrigal, M., Burciaga, A., Martínez, M. E., & Johnson, M. J. (2016). Technology-assisted stroke rehabilitation in Mexico: a pilot randomized trial comparing traditional therapy to circuit training in a Robot/technology-assisted therapy gym. Journal of neuroengineering and rehabilitation, 13(1), 83.

van Delden, A. E. Q., Beek, P. J., Roerdink, M., Kwakkel, G., & Peper, C. E. (2015). Unilateral and Bilateral Upper-Limb Training Interventions After Stroke Have Similar Effects on Bimanual Coupling Strength. Neurorehabilitation and Neural Repair, 29(3), 255-267.

van Delden, A. E. Q., Peper, C. E., Nienhuys, K. N., Zijp, N. I., Beek, P. J., & Kwakkel, G. (2013). Unilateral Versus Bilateral Upper Limb Training After Stroke The Upper Limb Training After Stroke Clinical Trial. Stroke, 44(9), 2613-2616.

van Dokkum, L. E. H., Ward, T., & Laffont, I. (2015). Brain computer interfaces for neurorehabilitation–its current status as a rehabilitation strategy post-stroke. Annals of physical and rehabilitation medicine, 58(1), 3-8.

van der Lee, J. H., Wagenaar, R. C., Lankhorst, G. J., Vogelaar, T. W., Devillé, W. L., & Bouter, L. M. (1999). Forced use of the upper extremity in chronic stroke patients: results from a single-blind randomized clinical trial. Stroke, 30(11), 2369-2375.

Vanoglio, F., Bernocchi, P., Mulè, C., Garofali, F., Mora, C., Taveggia, G., ... & Luisa, A. (2017). Feasibility and efficacy of a robotic device for hand rehabilitation in hemiplegic stroke patients: a randomized pilot controlled study. Clinical rehabilitation, 31(3), 351-360.ac

Van Peppen, R. P., Kwakkel, G., Wood-Dauphinee, S., Hendriks, H. J., Van der Wees, P. J., & Dekker, J. (2004). The impact of physical therapy on functional outcomes after stroke: what's the evidence?. Clinical rehabilitation, 18(8), 833-862.

van de Winckel, A., Feys, H., Lincoln, N., & De Weerdt, W. (2007). Assessment of arm function in stroke patients: Rivermead Motor Assessment arm section revised with Rasch analysis. Clinical rehabilitation, 21(5), 471-479.

van Vliet, P. M., Lincoln, N. B., & Foxall, A. (2005). Comparison of Bobath based and movement science based treatment for stroke: a randomised controlled trial. Journal of Neurology, Neurosurgery & Psychiatry, 76(4), 503-508.

Van Vugt, F. T., Ritter, J., Rollnik, J. D., & Altenmüller, E. (2014). Music-supported motor training after stroke reveals no superiority of synchronization in group therapy. Frontiers in human neuroscience, 8, 315.

van Wijck, F., Knox, D., Dodds, C., Cassidy, G., Alexander, G., & MacDonald, R. (2012). Making music after stroke: using musical activities to enhance arm function. Annals of the New York Academy of Sciences, 1252(1), 305-311.

Veldman, M. P., Zijdewind, I., Solnik, S., Maffiuletti, N. A., Berghuis, K. M. M., Javet, M., ... & Hortobágyi, T. (2015). Direct and crossed effects of somatosensory electrical stimulation on motor learning and neuronal plasticity in humans. European journal of applied physiology, 115(12), 2505-2519.

Viana, R. T., Laurentino, G. E. C., Souza, R. J. P., Fonseca, J. B., Silva Filho, E. M., Dias, S. N., ... & Monte-Silva, K. K. (2014). Effects of the addition of transcranial direct current stimulation to virtual reality therapy after stroke: a pilot randomized controlled trial. NeuroRehabilitation, 34(3), 437-446.

Volpe, B. T., Lynch, D., Rykman-Berland, A., Ferraro, M., Galgano, M., Hogan, N., & Krebs, H. I. (2008). Intensive sensorimotor arm training mediated by therapist or robot improves hemiparesis in patients with chronic stroke. Neurorehabilitation and Neural Repair, 22(3), 305-310.

Volpe, B. T., Ferraro, M., Lynch, D., Christos, P., Krol, J., Trudell, C., ... & Hogan, N. (2005). Robotics and other devices in the treatment of patients recovering from stroke. Current neurology and neuroscience reports, 5(6), 465-470.

Volpe, B. T., Krebs, H. I., Hogan, N., Edelstein, L., Diels, C., & Aisen, M. (2000). A novel approach to stroke rehabilitation: robot-aided sensorimotor stimulation. Neurology, 54(10), 1938-1944.

Volpe, B. T., Krebs, H. I., Hogan, N., Edelsteinn, L., Diels, C. M., & Aisen, M. L. (1999). Robot training enhanced motor outcome in patients with stroke maintained over 3 years. Neurology, 53(8), 1874-1874.

Volz, L. J., Rehme, A. K., Michely, J., Nettekoven, C., Eickhoff, S. B., Fink, G. R., & Grefkes, C. (2016). Shaping early reorganization of neural networks promotes motor function after stroke. Cerebral cortex, 26(6), 2882-2894.

Villán-Villán, M. A., Pérez-Rodríguez, R., Martín, C., Sánchez-González, P., Soriano, I., Opisso, E., ... & Gómez, E. J. (2018). Objective motor assessment for personalized rehabilitation of upper extremity in brain injury patients. NeuroRehabilitation, (Preprint), 1-11.

Vural, S. P., Yuzer, G. F. N., Ozcan, D. S., Ozbudak, S. D., & Ozgirgin, N. (2016). Effects of mirror therapy in stroke patients with complex regional pain syndrome type 1: a randomized controlled study. Archives of physical medicine and rehabilitation, 97(4), 575-581.

Waddell, K. J., Strube, M. J., Bailey, R. R., Klaesner, J. W., Birkenmeier, R. L., Dromerick, A. W., & Lang, C. E. (2017). Does task-specific training improve upper limb performance in daily life poststroke?. Neurorehabilitation and neural repair, 31(3), 290-300.

Walker, M. F., Sunderland, A., Fletcher-Smith, J., Drummond, A., Logan, P., Edmans, J. A., . . . Taylor, J. L. (2012). The DRESS trial: A feasibility randomized controlled trial of a neuropsychological approach to dressing therapy for stroke inpatients. Clinical Rehabilitation,26(8), 675-685.

Wang, C. C., Wang, C. P., Tsai, P. Y., Hsieh, C. Y., Chan, R. C., & Yeh, S. C. (2014). Inhibitory repetitive transcranial magnetic stimulation of the contralesional premotor and primary motor cortices facilitate poststroke motor recovery. Restorative neurology and neuroscience, 32(6), 825-835.

Wang, H., Zhang, C., Gao, C., Zhu, S., Yang, L., Wei, Q., & He, C. (2017). Effects of short-wave therapy in patients with knee osteoarthritis: a systematic review and meta-analysis. Clinical rehabilitation, 31(5), 660-671.

Wang, J., Yu, P., Zeng, M., Gu, X., Liu, Y., & Xiao, M. (2017). Reduction in spasticity in stroke patient with paraffin therapy. Neurological research, 39(1), 36-44.

Wang, Q. M., Cui, H., Han, S. J., Black-Schaffer, R., Volz, M. S., Lee, Y. T., ... & Fregni, F. (2014). Combination of transcranial direct current stimulation and methylphenidate in subacute stroke. Neuroscience letters, 569, 6-11.

Wang, Y. C., Wickstrom, R., Yen, S. C., Kapellusch, J., & Grogan, K. A. (2018). Assessing manual dexterity: Comparing the WorkAbility Rate of Manipulation Test with the Minnesota Manual Dexterity Test. Journal of Hand Therapy, 31(3), 339-347.

Wang, Q., Zhao, J. L., Zhu, Q. X., Li, J., & Meng, P. P. (2011). Comparison of conventional therapy, intensive therapy and modified constraint-induced movement therapy to improve upper extremity function after stroke. Journal of rehabilitation medicine, 43(7), 619-625.

Wang, W. W., Xie, C. L., Lu, L., & Zheng, G. Q. (2014). A systematic review and meta-analysis of Baihui (GV20)-based scalp acupuncture in experimental ischemic stroke. *Scientific reports*, *4*, 3981.

Ward, A., Carrico, C., Powell, E., Westgate, P. M., Nichols, L., Fleischer, A., & Sawaki, L. (2017). Safety and improvement of movement function after stroke with atomoxetine: A pilot randomized trial. Restorative neurology and neuroscience, 35(1), 1-10.

Ward, N. S., Brander, F., & Kelly, K. (2018). Intensive upper limb neurorehabilitation in chronic stroke: outcomes from the Queen Square programme. J Neurol Neurosurg Psychiatry, jnnp-2018.

Watanabe, K., Kudo, Y., Sugawara, E., Nakamizo, T., Amari, K., Takahashi, K., ... & Johkura, K. (2018). Comparative study of ipsilesional and contralesional repetitive transcranial magnetic stimulations for acute infarction. Journal of the neurological sciences, 384, 10-14.

Watkins, C. L., Leathley, M. J., Gregson, J. M., Moore, A. P., Smith, T. L., & Sharma, A. K. (2002). Prevalence of spasticity post stroke. Clinical rehabilitation, 16(5), 515-522.

Wayne, P. M., Krebs, D. E., Macklin, E. A., Schnyer, R., Kaptchuk, T. J., Parker, S. W., ... & Stason, W. B. (2005). Acupuncture for upper-extremity rehabilitation in chronic stroke: a randomized sham-controlled study. *Archives of physical medicine and rehabilitation*, *86*(12), 2248-2255.

Weber, D. J., Skidmore, E. R., Niyonkuru, C., Chang, C. L., Huber, L. M., & Munin, M. C. (2010). Cyclic functional electrical stimulation does not enhance gains in hand grasp function when used as an adjunct to onabotulinumtoxinA and task practice therapy: a single-blind, randomized controlled pilot study. Archives of physical medicine and rehabilitation, 91(5), 679-686.

Wei, X., Wang, S., Li, L., & Zhu, L. (2017). Clinical evidence of chinese massage therapy (Tui Na) for cervical radiculopathy: a systematic review and meta-analysis. Evidence-Based Complementary and Alternative Medicine, 2017.

Wei, X. J., Tong, K. Y., & Hu, X. L. (2011). The responsiveness and correlation between Fugl-Meyer Assessment, Motor Status Scale, and the Action Research Arm Test in chronic stroke with upper-extremity rehabilitation robotic training. International Journal of Rehabilitation Research, 34(4), 349-356.

Weimar, C., Konig, I. R., Kraywinkel, K., Ziegler, A., & Diener, H. C. (2004). Age and National Institutes of Health Stroke Scale Score within 6 hours after onset are accurate predictors of outcome after cerebral ischemia: development and external validation of prognostic models. Stroke, 35(1), 158-162.

Whitall, J., Waller, S. M., Sorkin, J. D., Forrester, L. W., Macko, R. F., Hanley, D. F., Goldberg, A. P., & Luft, A. (2011). Bilateral and unilateral arm training improve motor function through differing neuroplastic mechanisms: a single-blinded randomized controlled trial. Neurorehabil.Neural Repair, 25(2), 118-129.

Whitall, J., Waller, S. M., Silver, K. H., & Macko, R. F. (2000). Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. Stroke, 31(10), 2390-2395.

Wilson, J. L., Hareendran, A., Grant, M., Baird, T., Schulz, U. G., Muir, K. W., & Bone, I. (2002). Improving the assessment of outcomes in stroke: use of a structured interview to assign grades on the modified Rankin Scale. Stroke, 33(9), 2243-2246.

Wilson, D. J., Baker, L. L., & Craddock, J. A. (1984). Functional test for the hemiparetic upper extremity. The American Journal of Occupational Therapy, 38(3), 159-164.

Wilson, R. D., Page, S. J., Delahanty, M., Knutson, J. S., Gunzler, D. D., Sheffler, L. R., & Chae, J. (2016). Upper-limb recovery after stroke: a randomized controlled trial comparing EMG-

triggered, cyclic, and sensory electrical stimulation. Neurorehabilitation and neural repair, 30(10), 978-987.

Winstein, C. J., Wolf, S. L., Dromerick, A. W., Lane, C. J., Nelsen, M. A., Lewthwaite, R., ... & Azen, S. P. (2016). Effect of a task-oriented rehabilitation program on upper extremity recovery following motor stroke: the ICARE randomized clinical trial. Jama, 315(6), 571-581.

Winstein, C. J., Rose, D. K., Tan, S. M., Lewthwaite, R., Chui, H. C., & Azen, S. P. (2004). A randomized controlled comparison of upper-extremity rehabilitation strategies in acute stroke: a pilot study of immediate and long-term outcomes. Archives of physical medicine and rehabilitation, 85(4), 620-628.

Winstein, C. J., Rose, D. K., & Chui, H. C. (2001). Recovery and rehabilitation of arm use after stroke. J Stroke Cerebrovasc Dis, 10(4), 197.

Wittenberg, G. F., Chen, R., Ishii, K., Bushara, K. O., Taub, E., Gerber, L. H., ... & Cohen, L. G. (2003). Constraint-induced therapy in stroke: magnetic-stimulation motor maps and cerebral activation. Neurorehabilitation and neural repair, 17(1), 48-57.

Wittich, W., & Nadon, C. (2017). The Purdue Pegboard test: normative data for older adults with low vision. Disability and Rehabilitation: Assistive Technology, 12(3), 272-279.

Wolf, S. L., Sahu, K., Bay, R. C., Buchanan, S., Reiss, A., Linder, S., ... & Alberts, J. (2015). The HAAPI (Home Arm Assistance Progression Initiative) trial: a novel robotics delivery approach in stroke rehabilitation. Neurorehabilitation and neural repair, 29(10), 958-968.

Wolf, S. L., Milton, S. B., Reiss, A., Easley, K. A., Shenvi, N. V., & Clark, P. C. (2012). Further assessment to determine the additive effect of botulinum toxin type A on an upper extremity exercise program to enhance function among individuals with chronic stroke but extensor capability. Archives of physical medicine and rehabilitation, 93(4), 578-587.

Wolf, S. L., Thompson, P. A., Winstein, C. J., Miller, J. P., Blanton, S. R., Nichols-Larsen, D. S., ... & Sawaki, L. (2010). The EXCITE stroke trial: comparing early and delayed constraint-induced movement therapy. Stroke, 41(10), 2309-2315.

Wolf, S. L., Winstein, C. J., Miller, J. P., Thompson, P. A., Taub, E., Uswatte, G., ... & Clark, P. C. (2008). Retention of upper limb function in stroke survivors who have received constraint-induced movement therapy: the EXCITE randomised trial. *The Lancet Neurology*, *7*(1), 33-40.

Wolf, S. L., Winstein, C. J., Miller, J. P., Taub, E., Uswatte, G., Morris, D., ... & Excite Investigators. (2006). Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. Jama, 296(17), 2095-2104.

Wolf, S. L., Thompson, P. A., Morris, D. M., Rose, D. K., Winstein, C. J., Taub, E., ... & Pearson, S. L. (2005). The EXCITE trial: attributes of the Wolf Motor Function Test in patients with subacute stroke. Neurorehabilitation and neural repair, 19(3), 194-205.

Wolf, S. L., Catlin, P. A., Ellis, M., Archer, A. L., Morgan, B., & Piacentino, A. (2001). Assessing Wolf motor function test as outcome measure for research in patients after stroke. Stroke, 32(7), 1635-1639.

Woodbury, M. L., Howland, D. R., McGuirk, T. E., Davis, S. B., Senesac, C. R., Kautz, S., & Richards, L. G. (2009). Effects of trunk restraint combined with intensive task practice on poststroke upper extremity reach and function: a pilot study. Neurorehabilitation and Neural Repair, 23(1), 78-91.

Wu, C. W., Seo, H. J., & Cohen, L. G. (2006). Influence of electric somatosensory stimulation on paretic-hand function in chronic stroke. Archives of physical medicine and rehabilitation, 87(3), 351-357.

Wu, C. Y., Huang, P. C., Chen, Y. T., Lin, K. C., & Yang, H. W. (2013). Effects of mirror therapy on motor and sensory recovery in chronic stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 94(6), 1023-1030.

Wu, D., Qian, L., Zorowitz, R. D., Zhang, L., Qu, Y., & Yuan, Y. (2013). Effects on decreasing upper-limb poststroke muscle tone using transcranial direct current stimulation: a randomized sham-controlled study. Archives of physical medicine and rehabilitation, 94(1), 1-8.

Wu, C. Y., Yang, C. L., Chen, M., Lin, K. C., & Wu, L. L. (2013c). Unilateral versus bilateral robot-assisted rehabilitation on arm-trunk control and functions post stroke: a randomized controlled trial. Journal of NeuroEngineering and Rehabilitation, 10, 35.

Wu, C. Y., Chen, Y. A., Lin, K. C., Chao, C. P., & Chen, Y. T. (2012). Constraint-induced therapy with trunk restraint for improving functional outcomes and trunk-arm control after stroke: a randomized controlled trial. *Physical therapy*, *92*(4), 483-492.

Wu, C. Y., Chen, Y. A., Chen, H. C., Lin, K. C., & Yeh, I. L. (2012). Pilot trial of distributed constraint-induced therapy with trunk restraint to improve poststroke reach to grasp and trunk kinematics. Neurorehabilitation and neural repair, 26(3), 247-255.

Wu, C. Y., Chuang, L. L., Lin, K. C., Chen, H. C., & Tsay, P. K. (2011). Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. Neurorehabilitation and neural repair, 25(2), 130-139.

Wu, C. Y., Chen, C. L., Tang, S. F., Lin, K. C., & Huang, Y. Y. (2007). Kinematic and clinical analyses of upper-extremity movements after constraint-induced movement therapy in patients with stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 88(8), 964-970.

Wu, C. Y., Chen, C. L., Tsai, W. C., Lin, K. C., & Chou, S. H. (2007). A randomized controlled trial of modified constraint-induced movement therapy for elderly stroke survivors: changes in motor impairment, daily functioning, and quality of life. Archives of Physical Medicine and Rehabilitation, 88(3), 273-278.

Wu, C. Y., Lin, K. C., Chen, H. C., Chen, I. H., & Hong, W. H. (2007). Effects of modified constraint-induced movement therapy on movement kinematics and daily function in patients with stroke: a kinematic study of motor control mechanisms. Neurorehabilitation and neural repair, 21(5), 460-466.

Wu, H. C., Lin, Y. C., Hsu, M. J., Liu, S. M., Hsieh, C. L., & Lin, J. H. (2010). Effect of thermal stimulation on upper extremity motor recovery 3 months after stroke. Stroke, 41(10), 2378-2380.

Wu, M. T., Sheen, J. M., Chuang, K. H., Yang, P., Chin, S. L., Tsai, C. Y., ... & Pan, H. B. (2002). Neuronal specificity of acupuncture response: a fMRI study with electroacupuncture. Neuroimage, 16(4), 1028-1037.

Yadav, R. K., Sharma, R., Borah, D., & Kothari, S. Y. (2016). Efficacy of modified constraint induced movement therapy in the treatment of hemiparetic upper limb in stroke patients: a randomized controlled trial. Journal of clinical and diagnostic research: JCDR, 10(11), YC01.

Yang, S. Y., Lin, C. Y., Lee, Y. C., & Chang, J. H. (2017). The Canadian occupational performance measure for patients with stroke: a systematic review. Journal of physical therapy science, 29(3), 548-555.

Yang, Y. J., Zhang, J., Hou, Y., Jiang, B. Y., Pan, H. F., Wang, J., ... & Cheng, J. (2017). Effectiveness and safety of Chinese massage therapy (Tui Na) on post-stroke spasticity: a prospective multicenter randomized controlled trial. Clinical rehabilitation, 31(7), 904-912.

Yang CL, L. K., Chen HC, Wu CY, Chen CL. (2012). Pilot comparative study of unilateral and bilateral robot-assisted training on upper-extremity performance in patients with stroke. Am J Occup Ther., 66(2), 198-206.

Yang, N. Y., Fong, K. N., Li-Tsang, C. W., & Zhou, D. (2017). Effects of repetitive transcranial magnetic stimulation combined with sensory cueing on unilateral neglect in subacute patients with right hemispheric stroke: a randomized controlled study. Clinical rehabilitation, 31(9), 1154-1163.

Yang, Y. J., Zhang, J., Hou, Y., Jiang, B. Y., Pan, H. F., Wang, J., ... & Cheng, J. (2017). Effectiveness and safety of Chinese massage therapy (Tui Na) on post-stroke spasticity: a prospective multicenter randomized controlled trial. Clinical rehabilitation, 31(7), 904-912.

Yang, Y., Eisner, I., Chen, S., Wang, S., Zhang, F., & Wang, L. (2017). Neuroplasticity changes on human motor cortex induced by acupuncture therapy: a preliminary study. Neural plasticity, 2017.

Yao, W. J., & Ouyang, B. S. (2014). Effect of relaxing needling plus rehabilitation training on post-stroke upper limb dysfunction. Journal of Acupuncture and Tuina Science, 12(3), 146-149.

Yasar, E., Vural, D., Safaz, I., Balaban, B., Yilmaz, B., Goktepe, A. S., & Alaca, R. (2011). Which treatment approach is better for hemiplegic shoulder pain in stroke patients: intra-articular steroid or suprascapular nerve block? A randomized controlled trial. Clinical rehabilitation, 25(1), 60-68.

Yavuzer, G., Selles, R., Sezer, N., Sütbeyaz, S., Bussmann, J. B., Köseoğlu, F., ... & Stam, H. J. (2008). Mirror therapy improves hand function in subacute stroke: a randomized controlled trial. Archives of physical medicine and rehabilitation, 89(3), 393-398.

Yavuzer, G., Senel, A., Atay, M. B., & Stam, H. J. (2008). "Playstation eyetoy games"improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial. *European journal of physical and rehabilitation medicine*, *44*(3), 237-244.

Yoon, J. A., Koo, B. I., Shin, M. J., Shin, Y. B., Ko, H. Y., & Shin, Y. I. (2014). Effect of constraint-induced movement therapy and mirror therapy for patients with subacute stroke. Annals of rehabilitation medicine, 38(4), 458.

You, S. J., & Lee, J. H. (2013). Effects of mental activity training linked with electromyogram-triggered electrical stimulation on paretic upper extremity motor function in chronic stroke patients: a pilot trial/Kronik felcli hastalarda paretik ust ekstremite motor fonksiyonlari uzerinde elektromiyografi ile tetiklenen elektrik stimulasyonu esliginde mental aktivite egitiminin etkileri: pilot calisma. Turkish Journal of Physical Medicine and Rehabilitation, 59(2), 133-140.

You, Y. Y., Her, J. G., Woo, J. H., Ko, T., & Chung, S. H. (2014). The effects of stretching and stabilization exercise on the improvement of spastic shoulder function in hemiplegic patients. Journal of physical therapy science, 26(4), 491-495.

Yue, Z., Zhang, X., & Wang, J. (2017). Hand rehabilitation robotics on poststroke motor recovery. Behavioural neurology, 2017.

Yue, S., Jiang, X., & Wong, T. (2013). Effects of a nurse-led acupressure programme for stroke patients in China. Journal of clinical nursing, 22(7-8), 1182-1188.

Yun, G. J., Chun, M. H., Park, J. Y., & Kim, B. R. (2011). The synergic effects of mirror therapy and neuromuscular electrical stimulation for hand function in stroke patients. Annals of rehabilitation medicine, 35(3), 316.

Yuzer, G. F. N., Dönmez, B. K., & Özgirgin, N. (2017). A Randomized Controlled Study: Effectiveness of Functional Electrical Stimulation on Wrist and Finger Flexor Spasticity in Hemiplegia. Journal of Stroke and Cerebrovascular Diseases, 26(7), 1467-1471.

Zeuner, K. E., Knutzen, A., Kühl, C., Möller, B., Hellriegel, H., Margraf, N. G., ... & Stolze, H. (2017). Functional impact of different muscle localization techniques for Botulinum neurotoxin A injections in clinical routine management of post-stroke spasticity. *Brain injury*, *31*(1), 75-82.

Zhang, Y., Al-Aref, R., Fu, H., Yang, Y., Feng, Y., Zhao, C., ... & Sun, G. (2017). Neuronavigation-Assisted Aspiration and Electro-Acupuncture for Hypertensive Putaminal Hemorrhage: A Suitable Technique on Hemiplegia Rehabilitation. Turk Neurosurg, 27(4), 500-508.

Zhang, J., Mu, X., Breker, D. A., Li, Y., Gao, Z., & Huang, Y. (2017). Atorvastatin treatment is associated with increased BDNF level and improved functional recovery after atherothrombotic stroke. International Journal of Neuroscience, 127(1), 92-97.

Zhang, L., Xing, G., Fan, Y., Guo, Z., Chen, H., & Mu, Q. (2017). Short-and long-term effects of repetitive transcranial magnetic stimulation on upper limb motor function after stroke: a systematic review and meta-analysis. Clinical rehabilitation, 31(9), 1137-1153.

Zhang, Y., Cai, J., Zhang, Y., Ren, T., Zhao, M., & Zhao, Q. (2016). Improvement in stroke-induced motor dysfunction by music-supported therapy: a systematic review and meta-analysis. Scientific reports, 6, 38521.

Zhang, Y., Cai, J., Zhang, Y., Ren, T., Zhao, M., & Zhao, Q. (2016). Improvement in stroke-induced motor dysfunction by music-supported therapy: a systematic review and meta-analysis. Scientific reports, 6, 38521.

Zhao, J. G., Cao, C. H., Liu, C. Z., Han, B. J., Zhang, J., Li, Z. G., ... & Xu, Z. H. (2009). Effect of acupuncture treatment on spastic states of stroke patients. Journal of the neurological sciences, 276(1-2), 143-147.

Zhao, W., Wang, C., Li, Z., Chen, L., Li, J., Cui, W., ... & Xiao, S. (2015). Efficacy and safety of transcutaneous electrical acupoint stimulation to treat muscle spasticity following brain injury: a double-blinded, multicenter, randomized controlled trial. PLoS One, 10(2), e0116976.

Zheng, C. J., Liao, W. J., & Xia, W. G. (2015). Effect of combined low-frequency repetitive transcranial magnetic stimulation and virtual reality training on upper limb function in subacute stroke: a double-blind randomized controlled trail. Journal of Huazhong University of Science and Technology [Medical Sciences], 35(2), 248-254.

Zhuang, L. X., Xu, S. F., D'Adamo, C. R., Jia, C., He, J., Han, D. X., & Lao, L. X. (2012). An Effectiveness Study Comparing Acupuncture, Physiotherapy, and Their Combination in Poststroke Rehabifitation: A Multicentered, Randomized, Controlled Clinical Trial. Alternative Therapies in Health & Medicine, 18(3).

Zhu, M. H., Wang, J., Gu, X. D., Shi, M. F., Zeng, M., Wang, C. Y., ... & Fu, J. M. (2015). Effect of action observation therapy on daily activities and motor recovery in stroke patients. International Journal of Nursing Sciences, 2(3), 279-282.

Zimerman, M., Heise, K. F., Hoppe, J., Cohen, L. G., Gerloff, C., & Hummel, F. C. (2012). Modulation of training by single-session transcranial direct current stimulation to the intact motor cortex enhances motor skill acquisition of the paretic hand. Stroke, 43(8), 2185-2191.

Zittel, S., Weiller, C., & Liepert, J. (2008). Citalopram improves dexterity in chronic stroke patients. Neurorehabilitation and neural repair, 22(3), 311-314.

Zittel, S., Weiller, C., & Liepert, J. (2007). Reboxetine improves motor function in chronic stroke. Journal of neurology, 254(2), 197-201.

Zondervan, D. K., Friedman, N., Chang, E., Zhao, X., Augsburger, R., Reinkensmeyer, D. J., & Cramer, S. C. (2016). Home-based hand rehabilitation after chronic stroke: Randomized, controlled single-blind trial comparing the MusicGlove with a conventional exercise program. Journal of Rehabilitation Research & Development, 53(4).

Zondervan, D. K., Augsburger, R., Bodenhoefer, B., Friedman, N., Reinkensmeyer, D. J., & Cramer, S. C. (2015). Machine-based, self-guided home therapy for individuals with severe arm impairment after stroke: a randomized controlled trial. Neurorehabilitation and neural repair, 29(5), 395-406.