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Review of the randomized clinical stroke rehabilitation trials in 2009

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Summary

Background: Recent review of the available evidence on interventions for motor recovery after stroke, showed that improvements in recovery of arm function were seen for constraint-induced movement therapy, electromyographic biofeedback, mental practice with motor imagery, and robotics. Similar improvement in transfer ability or balance were seen with repetitive task training, biofeedback, and training with a moving platform. Walking speed was improved by physical fitness training, high-intensity physiotherapy and repetitive task training. However, most of these trials were small and had design limitations.

Material/Methods: In this article, randomized control trials (RCT's) published in 2009 of rehabilitation therapies for acute (≤2 weeks), sub-acute (2 to 12 weeks) and chronic (≥12 weeks) stroke was reviewed. A Medline search was performed to identify all RCT's in stroke rehabilitation in the year 2009. The search strategy that was used for PubMed is presented in the Appendix 1. The objective was to examine the effectiveness of these treatment modalities in stroke rehabilitation.

Results: This generated 35 RCT's under 5 categories which were found and analyzed. The methodological quality was assessed by using the PEDro scale for external and internal validity.

Conclusions: These trials were primarily efficacy studies. Most of these studies enrolled small numbers of patient which precluded their clinical applicability (limited external validity). However, the constraint induced movement therapy (CIT), regularly used in chronic stroke patients did not improve affected arm-hand function when used in acute stroke patients at ≤4weeks. Intensive CIT did not lead to motor improvement in arm-hand function. Robotic arm treatment helped decrease motor impairment and improved function in chronic stroke patients only. Therapist provided exercise programs (when self-administered by patients during their off-therapy time in a rehabilitation setting) did improve arm-hand function. Tai Chi exercises helped improve balance and weight bearing. Exercise programs for community dwelling stroke patient helped maintain and even improve their functional state.

key words: **stroke • rehabilitation • RCT's**

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Background

This review comments about the clinical usefulness of treatment modalities both experimental as well as commonly used and readily available to physicians and therapists caring for stroke patients, that were assessed in randomized clinical trials published in 2009.

Arm and Hand

More than 70% of individuals experience upper limb weakness post-stroke [2]. Thirty percent of these patients have a permanently weak arm and hand. This limits their ability to function independently, despite rehabilitation. There is a strong relationship between upper limb function and ability to perform activities of daily living [3,4].

L2 Mirror therapy promotes recovery from severe hemiparesis: a randomized controlled trial

Since rehabilitation of a paretic arm after stroke represents a major challenge, especially in the presence of sensory impairment, this study evaluated the effect of mirror therapy (MT) to simulate movement in the affected upper extremity by moving the unaffected upper extremity early after stroke. In the MT a mirror is placed in the patient's mid-sagittal plane with the affected arm behind the mirror. While seated the patient moves the unaffected arm while watching the mirror image as if it were the affected arm. Thirty-six patients, with arm-hand hemiplegia because of a first-ever ischemic stroke in the territory of the middle cerebral artery, were enrolled within 8 weeks after the stroke. They initially underwent standard therapy, and then completed 6 weeks of additional therapy (30 minutes a day, 5 days a week), with random assignment to either MT (n=18) or an equivalent control therapy (CT, n=18) [5]. The primary outcome measure was the Fugl-Meyer total and subscores for the upper extremity evaluated by independent raters through videotape. The secondary outcome measures were: Action Research Arm Test, motor part of the Functional Independent Measure, and the Behavioral Inattention Test. In a subgroup of 25 patients with distal plegia at the beginning of the therapy, MT patients regained more distal function than CT patients. MT also improved recovery of surface sensibility and from hemineglect. These improvements were independent of the side of the lesioned hemisphere. Thus MT early after stroke is a promising method to improve sensory and attentional deficits and to support motor recovery in a distal plegic limb.

A randomized controlled trial of mental imagery augment generalization of learning in acute poststroke patients

Mental imagery intervention has been shown to enhance poststroke patients relearning daily task performance [6]. This study assessed the efficacy of mental imagery in promoting generalization of the task skills learned in a training environment to trained and untrained tasks carried out in a novel environment. Thirty-five acute poststroke patients were randomly assigned to the mental imagery (MI; n=18) or conventional functional rehabilitation (FR; n=17) group [7]. The MI intervention was 15 1 hour daily session for 5-days per week for 3 weeks. The standardized practices and daily tasks were broken down into 3 separate activities: chunking-self regulation-mental rehearsal strategies. Outcome measurements were the performances on trained and untrained tasks in both training and novel environments. The MI patients showed significantly better performances on 4 of 5 trained tasks (P=0.001 to 0.026) versus only 1 task in the FR patients (P=0.021). The MI patients also outperformed their FR counterpart on the 3 of 5 (P=0.025 to 0.049) trained and 2 of 3 untrained tasks (P=0.042 to 0.045) carried out in the novel environment. Thus mental imagery intervention was useful for improving patients' ability to perform the tasks that they were not previously trained on, and in places different from the training environments. The stroke severity (measured by Barthel Index) had no influence on task performance in the MI group while in the FR group if did influence outcome.

Surface electrical stimulation (ES) has been shown to improve the motor impairment of stroke survivors [8] by modifying the corticospinal-anterior horn cell synapses [9]. This allows active exercises to be undertaken in stroke patients with upper limb weakness.

Motor training of upper extremity with functional electrical stimulation in early stroke rehabilitation

In this pilot study the effect of motor training with Functional Electrical Stimulation (FES) on motor recovery, in acute and subacute stroke patients with severe to complete arm and/or hand paralysis, was assessed. Twenty three acute and subacute stroke patients were randomly assigned to the intervention (n=12) and control group (n=11) [10]. Over a 4 week period, FES training replaced 12 conventional training sessions in the intervention group. An Extended Barthel Index (EBI) subscore assessed the performance of activities of daily living (ADL). The Chedoke McMaster Stroke Assessment (CMSA) measured hand and arm function and shoulder pain. The Modified Ashworth Scale (MAS) assessed resistance to passive movement. These assessments were performed by an unblinded assessor prior to and following the end of the training period. The EBI subscore and CMSA arm score improved significantly in both groups. Shoulder pain did not change significantly, and none of the outcome measures showed significant gain differences between the groups. The CMSA hand function and resistance to passive movement of finger and wrist flexors improved significantly in the FES group. The study showed lack of clear evidence for superiority or inferiority of FES. The authors of this study suggested that at least 24 sessions were needed to test for superiority of FES in these severely impaired patients and approximately 50 participants would need to be assigned to each therapeutic intervention to find significant differences. Another important limitation was that the evaluation was performed by an unblinded assessor: this can bias the study results.

Bilateral upper limb training with functional electric stimulation in patients with chronic stroke

This study aimed to investigate the effectiveness of functional electric stimulation (FES) with bilateral activities training to improve upper limb function. In this double-blinded randomized controlled trial 20 patients were recruited 6 months after the onset of stroke and completed 15 training sessions. Participants were randomly assigned to the FES (n=10) or to the control (n=10) group [11]. Each session consisted of stretching activities (10 minutes), FES with bilateral tasks (20 minutes), and occupational therapy treatment (60 minutes). The participants used a self-trigger mechanism, with an accelerometer as a motion detector, for generating an electric stimulation pattern that was synchronized with the bilateral upper limb activities during the training. The participants in the control group received the same duration of stretching and occupational therapy training, with placebo stimulation in the bilateral tasks. The outcome measures included Functional Test for the Hemiplegic Upper Extremity (FTHUE), Fugl-Meyer Assessment (FMA), and grip power, forward reaching distance, active range of motion of wrist extension, Functional Independence Measure, and Modified Ashworth Scale. At baseline comparison, there was no significant difference between the two groups. After 15 training sessions, the FES group had significant improvement in FMA (P=.039), FTHUE (P=.001), and active range of motion of wrist extension (P=.020) compared to the control group. The findings of this small study needs to be replicated in a larger powered study before bilateral upper limb training with FES is incorporated as a treatment modality for upper limb rehabilitation of stroke patients.

Increased pinch strength in acute and sub-acute stroke patients after simultaneous median and ulnar sensory stimulation

A therapeutic modality suggested is peripheral nerve stimulation to induce cortical changes and help improve pinch strength in chronic stroke patients immediately after stimulation. In this randomized, single-blinded, controlled study 20 stroke patients with an onset less than 6 months, who could voluntarily pinch the thumb to the index finger, were enrolled. Ten patients received a single 2 hour session of simultaneous electrical stimulation over the median and ulnar nerves at the wrist to the level of appreciating paresthesias (peripheral sensory stimulation group). Ten control patients received stimulation to the level of perception (sham-control group) [12]. Pinch strength of the thumb pad to tip and to lateral side of the index finger of the paretic hand and the Action Research Arm test (ARAT) were tested before and immediately after the stimulation. Lateral and tip pinch strength increased in both groups (P<.05). Mean ±SD of increased lateral pinch strength for the peripheral sensory stimulation and sham-control groups were 1.24±0.54 pounds and 0.20±0.28 pounds respectively. Mean ±SD of increased tip pinch strength for peripheral sensory stimulation and sham-control groups were 1.00±0.72 pounds and 0.37±0.36 pounds respectively. Increase in the pinch strength of the peripheral sensory stimulation group was greater than the sham-control group (P<.05). The Action Research Arm test was not significantly different after stimulation in both groups (P>.05). The authors of the study concluded that peripheral sensory stimulation of the paretic hand increased pinch strength of acute and subacute stroke patients immediately after stimulation. This study has several limitations. In addition to the small sample size of 20 patients (10 patients in each group), patients in the peripheral sensory stimulation group were 12±11 days post-stroke to 39±54 days for the sham-control group. This difference in outcome could easy be explained on the time-to-stroke onset favoring the intervention group. Third, patients in this study had minimal arm-hand weakness based on the baseline ARAT score. It would have been worth demonstrating the effect of this treatment in stroke patients with moderate to severe arm-hand weakness in improving motor function; these are the patients who need the most help.

Intramuscular electrical stimulation for upper limb recovery in chronic hemiparesis: An exploratory randomized clinical trial

Surface electrical stimulation (ES) can be painful with inconsistent motor activation from session to session due to difficulty in localizing motor points for electrode placement. Percutaneous intramuscular ES may be an effective alternative with the electrodes implanted at selective motor points. This study evaluated the effectiveness of percutaneous intramuscular ES in facilitating the recovery of the hemiparetic upper limb of chronic stroke survivors. A total of 26 chronic stroke survivors (≥12 weeks) attending an out-patient rehabilitation unit were randomly assigned to percutaneous intramuscular ES for hand opening (n=13) or percutaneous ES for sensory stimulation only (n=13) [13]. The intramuscular ES group received either cyclic, electromyography (EMG)-triggered or EMG-controlled ES depending on baseline motor status. All participants received 1 hour of stimulation per day for 6 weeks. After completion of ES, participants received 18 hours of task-specific functional training. The primary outcome measure was the Fugl-Meyer Motor Assessment. Secondary measures included the Arm Motor Ability Test. Outcomes were assessed in a blinded manner at baseline, at the end of ES, at the end of functional training, and at 1, 3, and 6 months follow-up. Repeated measure analysis of variance did not yield any significant treatment, or time by treatment interaction effects for any of the outcome measures between the 2 groups. Thus, percutaneous intramuscular ES was no more effective than sensory ES in enhancing the recovery of the hemiparetic upper limb among chronic stroke survivors. The study limitations were: i) small sample size with inadequate power to detect differences, ii) administration of concomitant therapy such as botulinum toxin injections, iii) motor ES group received heterogeneous treatment EMG-triggered *vs.* EMG controlled, and iv) finally the dose and intensity of ES may have been inadequate.

Constraint induced therapy has been found to be effective for overcoming learned non-use [14]. However, this task specific intensive training of the affected arm and hand (6 hours/day, 5 sessions per week, for 2 weeks) may not be acceptable to many patients [15] and is responsible for being applicable to 10% of stroke patient population [16].

Constraint-induced therapy versus dose-matched control intervention to improve motor ability, basic/extended daily functions, and quality of life in stroke

Trials of constraint-induced movement therapy (CIT) to improve upper extremity function after stroke have not often included an actively treated control group. This study compared modified CIT intervention with a dose-matched control intervention that included restraint of the less affected hand and assessed for differences in motor and functional performance and health-related quality of life. This randomized controlled trial, using pre-treatment and post-treatment measures enrolled 32 patients within 6 to 40 months after onset of a first stroke (mean age: 55.7 years).

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They received either CIT (n=16) (restraint of the unaffected limb combined with intensive training of the affected limb for 2 hours daily 5 days per week for 3 weeks, plus additional restraint of the unaffected hand for 5 hours outside of the rehabilitation training) or a conventional intervention (n=16) with hand restraint for the same duration [17]. The outcome measures were the Fugl-Meyer Assessment, Functional Independence Measure, Motor Activity Log, Nottingham Extended Activities of Daily Living Scale, and Stroke Impact Scale. Compared to the control group, the CIT group exhibited significantly better performance in motor function, level of functional independence, mobility of extended activities during daily life, and health-related quality of life after treatment. Thus CIT group improved in various outcome measures, including motor function, basic and extended functional ability, and quality of life. No significant differences after treatment existed between the 2 groups for cognitive and psychosocial domains.

Effects of constraint-induced therapy versus bilateral arm training on motor performance, daily functions, and quality of life in stroke survivors

This study investigated the relative effects of modified constraint-induced therapy (CIT) and bilateral arm training (BAT) on motor performance, daily function, functional use of the affected arm, and quality of life in patients with hemiparetic stroke. Sixty patients attending an out-patient rehabilitation program were randomized to modified CIT (n=20), BAT (n=20), or a control (n=20) intervention of less specific but active therapy. Each group received intensive training for 2 hours/day, 5 days/week, for 3 weeks [18]. Pretreatment and posttreatment measures included the Fugl-Meyer Assessment (FMA), Functional Independence Measure (FIM), Motor Activity Log (MAL), and Stroke Impact Scale (SIS). The proximal and distal scores of FMA were used to examine separate upper limb (UL) elements of movement. Overall performance score improved on the FMA in the modified CIT and BAT groups than in the control group. The BAT group achieved greater gains in the proximal part of the FMA score than the modified CIT and control groups. Enhanced performance was achieved by the modified CIT group in the MAL, the FIM motor-subscale, and ADL/IADL domains of the SIS. In this study BAT improved proximal UL motor impairment while modified CIT produced greater functional gains for the affected UL in patient with mild to moderate chronic hemiparesis.

Effects of trunk restraint combined with intensive task practice on poststroke upper extremity reach and function: a pilot study

Poststroke reaching is characterized by excessive trunk motion and abnormal shoulder-elbow coordination. Little attention has been given to arm-trunk kinematics during task practice. This study compared the effects of intensive task practice with and without trunk restraint on poststroke reaching kinematics and function. Eleven individuals with chronic stroke (≥3 months), baseline Fugl-Meyer Upper Extremity Assessment scores 26 to 54, were randomized to 2 constraint-therapy intervention groups [19]. All participants wore a mitt on the unaffected hand for 90% of waking hours over 14 days and participated for 6 hours/day for 10 days of supervised progressive task practice. During supervised sessions, one group trained with a trunk restraint (n=6, preventing anterior trunk motion) while another group did not (n=5). Tasks for the trunk-restraint group involved repeated use of a shoulder flexion-elbow extension reaching pattern. Outcome measures included kinematics of unrestrained targeted reaching and tests of functional arm ability. Post-training, the trunk-restraint group demonstrated straighter reach trajectories (P=.000) and less trunk displacement (P=.001). The trunk-restraint group gained shoulder flexion (P=.006) and elbow extension (P=.022) voluntary ranges of motion; the nonrestraint group did not. Both groups gained the ability to use the arms functionally (P<.05 all tests). In this study intensively structured task practice was able to prevent compensatory trunk movements and promote shoulder flexion-elbow extension coordination reinforced development of "normal" reaching kinematics.

Very Early Constraint-Induced Movement during Stroke Rehabilitation (VECTORS): A single-center RCT.

A phase III randomized control trial of Constraint-induced movement therapy (CIT) initiated in chronic stroke patients (3- to 9-month period post-stroke) found CIT to be superior to the usual customary care with persistent treatment response [20]. Very Early Constraint-Induced Movement during Stroke Rehabilitation (VECTORS) was a single-blind phase II trial of CIT during acute inpatient rehabilitation comparing traditional UE therapy with dose-matched and high-intensity CIT protocols. Participants were randomized on rehabilitation admission to either CIT (n=35; low intensity=19, high intensity=16) or control (n=17) group [21]. The low intensity CIT group received 2 hours of shaping therapy per day and wore mittens for 6 hours per day, while high intensity CIT group received 3 hours of shaping therapy per day and wore mittens for 90% waking hours. The control group received compensatory techniques for ADLs, range of motion and strengthening. Both groups received 2 weeks of study-related treatments. The primary endpoint was the total Action Research Arm Test (ARAT) score of the affected arm-hand at 90 days after stroke onset. A total of 52 participants (mean age 63.9±14 years) were randomized 9.65±4.5 days after onset. Mean NIHSS was 5.3±1.8; mean total ARAT score was 22.5±15.6; 77% had ischemic stroke. Both groups were equivalent at baseline on all randomization variables. Both groups improved with time on the total ARAT score. There was a significant time x group interaction (F=3.1, p<0.01), such that the high intensity CIT group had significantly less improvement at day 90. No significant differences were found between the dose-matched CIT and control groups at day 90. MRI of a subsample showed no evidence of activity-dependent lesion enlargement. Thus CIT was not superior to an equal dose of traditional therapy during inpatient stroke rehabilitation. Higher intensity CIT resulted in less motor improvement at 90 days, indicating an inverse dose-response relationship. This study highlights the need for motor intervention trials to control for dose. Higher doses of motor training need not be assumed to be more beneficial, particularly early after stroke.

Is forced use of the paretic upper limb beneficial? A randomized pilot study during subacute post-stroke recovery

This study evaluated the effect of two weeks of forced use of the paretic upper limb as a supplement to the on-going rehabilitation program in the sub-acute phase after stroke. In this randomized, non-blinded study, there were 15 patients in the forced use and 15 patients in the conventional group [22]. Both group of patients participated in 2-weeks of daily training on weekdays. In addition, the forced use group wore a restraining sling on the non-paretic arm for 6 hours/weekday. Both groups were followed at 1- and 3-months after the intervention. The main measure was the Motor Activity Log which the patients scored (0–5) for 30 daily tasks based on both the amount of use and quality of movement. The forced use group achieved greater improvements immediately post-intervention, but this was not significant. At 3-month follow-up, both groups achieved 1.0 score point on both scales of the Motor Activity Log. Thus, in this pilot study additional benefit of forced use on self-rated performance in daily use of the paretic upper limb was not obtained.

A self-administered Graded Repetitive Arm Supplementary Program (GRASP) improves arm function during inpatient stroke rehabilitation: a multi-site randomized controlled trial

Post-stroke patients spend more than 60% of their day resting and alone [23], however; a practical and inexpensive self-administered therapy for arm weakness would help improve its function and their ability to perform activities of daily living. With this in mind, a multi-site single blinded randomized controlled trial was undertaken to determine the effectiveness of a 1-hour daily, 6 days per week for 4 weeks self-administered graded repetitive upper limb supplementary program (GRASP) on arm recovery in stroke. One hundred and three patients (2 weeks post-stroke in an acute rehabilitation unit) were randomized to the experimental group (GRASP, which included exercises aiming for arm and hand strengthening, range of movement, gross and fines motor skills, and task oriented activities of daily living; n=53) or the control group (stroke education, recovery and general health information; n=50) [24]. The primary outcome measure was the Chedoke Arm and Hand Activity Inventory (CAHAI), a measure of upper limb function in activities of daily living. Secondary measures evaluated grip strength and paretic upper limb use outside of therapy time. Intention-to-treat analysis was performed. Group differences were tested using analysis of covariance. At the end of the 4-week intervention, the GRASP group showed greater improvement in upper limb function (CAHAI) compared to the control group (mean difference 6.2; 95% CI: 3.4 to 9.0; P<0.001). The GRASP group maintained this improvement at 5 months poststroke. There was significant improvement in favor of the GRASP protocol for grip strength and paretic upper limb use. No serious adverse effects were experienced. Thus a self-administered homework exercise program such as GRASP was found to be a safe, cost, time, and treatment effective delivery model for improving upper limb recovery in patients with subacute stroke.

A randomized controlled trial of gravity-supported, computer-enhanced arm exercise for individuals with severe hemiparesis

A passive instrumented arm orthosis (Therapy Wilmington Robotic Exoskeleton [T-WREX]) was developed to enable individuals with hemiparesis to exercise the arm by playing computer games in a gravity-supported environment. This study compared the semiautonomous training with the T-WREX to conventional semiautonomous exercises that used a tabletop for gravity support. Twenty-eight chronic stroke survivors (≥6 months post-stroke) with moderate/severe hemiparesis were randomly assigned to experimental (T-WREX, n=14) or control (tabletop exercise, n=14) treatment [25]. A blinded rater assessed arm movement before and after 24 1-hour treatment sessions (3 times per week for 8 weeks) and at 6-month follow-up. Subjects also rated subjective treatment preferences after a single-session crossover treatment. All subjects significantly improved (PP<=≤0.05) upper extremity motor control (Fugl-Meyer), active reaching range of motion (ROM), and self-reported quality and amount of arm use (Motor Activity Log). Improvements were sustained at 6 months. The T-WREX group maintained gains on the Fugl-Meyer significantly better than controls at 6 months (improvement of 3.6±3.9 *vs.* 1.5±2.7 points, mean ±SD; P=0.04). Subjects reported a preference for T-WREX training. Thus gravity-supported arm exercises using the T-WREX or tabletop support, do improve arm movement ability after chronic severe hemiparesis with brief one-on-one assistance from a therapist (approximately 4 minutes per session). The 3-dimensional weight support, instant visual movement feedback, and simple virtual reality software provided by T-WREX provided modest gains at 6-month follow-up when compared with the conventional approach.

A comparison between electromyography-driven robot and passive motion device on wrist rehabilitation for chronic stroke

With robots being increasing used to improve motor recovery, this study aimed to compare the training effects of treatments on the wrist joint of subjects with chronic stroke using an electromyography (EMG)-driven robot versus a robot with continuous passive motion. In this single-center single-blinded randomized controlled trial with a 3-month follow-up, 27 hemiplegic subjects with chronic stroke were randomly assigned to receive either 20-sessions of wrist training with a continuous electromyography (EMG)-driven robot (interactive group, n=15) or a passive motion device (passive group, n=12); they were completed within 7 consecutive weeks [26]. Training effects were evaluated by pre-training and post-training tests (Fugl-Meyer Assessment [FMA] and Modified Ashworth Score [MAS]) and with session-by-session EMG parameters (EMG activation level and co-contraction index). Significant improvements in FMA scores (shoulder/elbow) were found in the interactive group (P<.05). Significant decreases in the MAS scores were observed in the wrist and elbow joints for the interactive group and in the wrist joint for the passive group (P<.05). These MAS changes were associated with the decrease in EMG activation level of the flexor carpi radialis and the biceps brachii for the interactive group (P<.05). The muscle coordination on wrist and elbow joints improved in the interactive groups in the EMG co-contraction indexes across the training sessions (P<.05). However, there was no effect on the ARAT and FIM scores in both treatment groups (p≥0.5). Thus, the interactive treatment improved muscle coordination and reduced spasticity after the training for both the wrist and elbow joints, which persisted for 3 months, while the passive mode training mainly reduced the spasticity in the wrist flexor. Neither robot approaches

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improved arm-hand function. This study result is biased, as patients who were motivated volunteered for the study in order to improve themselves.

Progressive shoulder abduction loading is a crucial element of arm rehabilitation in chronic stroke

Diminished or absent shoulder abduction in the paretic arm in individuals with chronic hemiparetic stroke decreases the total reaching range of motion when reaching outward against gravity or during transport of an object. In this study, 14 individuals with chronic moderate to severe hemiparesis (Fugl-Meyer Motor Assessment scores between 10 and 43 [normal=66]) were randomized to either experimental group (n=7) or the control group (n=7) [27]. The experimental group received a total of 3 sessions per week over an 8-week period with a progressive increase by 25% of arm weight actively supported by the participant while reaching for various outward targets. The control group practiced the same reaching tasks with matched frequency and duration with the weight of the arm supported. Work area and isometric strength were measured before and after the intervention. Shoulder abduction loading was expressed as a percentage of arm weight the subject was expected to support during the tasks. It ranged from 0% to 200% of arm weight in increments of 25%. There was a significant increase (26% to 68%) in the change scores for work area at 9 different loads in the experimental group at the limb-loading levels of 50%, 100%, 125% and 175% ($p \leq 0.05$). This increase in the change score for work area was not associated with an increase in muscle strength within or between groups. This result suggests that in patients with sufficient strength to elevate their arm against gravity multi-joint coordination as opposed to single-joint strengthening helped achieve this increasing range of reaching activity. Thus progressive shoulder abduction loading can be utilized to ameliorate reaching range of motion against gravity.

The effect of local injections in hemiplegic shoulder pain

This study aimed to evaluate the effects of corticosteroid injections on hemiplegic shoulder pain and range of motion. Thirty-eight patients admitted to a rehabilitation hospital with either an ischemic or a hemorrhagic stroke 8-weeks prior were randomly assigned to either injection (n=21) or control (n=17) groups [28]. Both groups of patients received 15 sessions each lasting 20-minutes of transcutaneous electrical nerve stimulation and therapeutic exercise program over a 3-week period. Both groups of patients were also allowed to take acetoaminophen if needed. The patients in the injection group were administered either intra-articular or subacromial injections of 1 ml of triamcinolone (corticosteroid) and 9 ml of prilocain (local anesthetic). The primary outcome measures were passive range of shoulder motion and verbal analog scale for shoulder pain. The secondary outcome measures were modified Barthel index, Brunnstrom upper-extremity score, and modified Ashworth scale. The range of shoulder motion and shoulder pain scores improved in both group of patients; however, improvement was more significant in the injection group. Barthel scores improved in both groups, with no difference between the groups. Brunnstrom upper-extremity and modified Ashworth scores showed no significant changes in both groups. The study concluded that adding corticosteroid injection to conventional treatment in hemiplegic shoulder pain improved range of shoulder motion and decreased pain scores, and recommended corticosteroid injection in hemiplegic shoulder pain in appropriate patients. This conclusion is somewhat suspect for the following reasons: i) there was clinical improvement in both groups, ii) there was no placebo control, iii) the sample size was small, and iv) the study was unblinded.

Enhancing motor performance by anodal transcranial direct current stimulation in the subacute stroke patients

This study investigated whether anodal transcranial direct current stimulation (tDCS) enhances motor performance in the paretic hand of subacute poststroke patients and for how long does any improvement persist after the session was completed. Ten patients with an ischemic or a hemorrhagic stroke within the past 12 weeks, with a motor weakness of ≥3 but <5 on the Medical Research Council scale, were recruited for this single-blinded, sham-controlled, crossover study. Anodal tDCS 1 mA (n=5) or sham (n=5) stimulation was randomly delivered on the hot spot of the 1st dorsal interosseous in the affected hemisphere. The duration of tDCS was 20 mins and sham was 30 secs [29]. The Box and Block test and finger acceleration measurement were performed before, during, immediately after, and 30 and 60 minutes after anodal or sham stimulation, to assess time-dependent changes in motor performance. Finger acceleration measurement and Box and Block test significantly improved after anodal tDCS compared with sham stimulation ($P<0.05$). This improvement lasted for 30 minutes for the finger acceleration measurement and 60 minutes for the Box and Block test ($P<0.05$), with no effect on attention and fatigue. Thus anodal tDCS on the affected hemisphere can enhance motor performance of the hemiparetic hand transiently, outlasting the stimulation session.

Comparison of bilateral and unilateral training for upper extremity hemiparesis in stroke

This randomized, blinded controlled study compared the efficacy of 2 groups (bilateral training *vs.* unilateral training) using analogous tasks performed in chronic stroke survivors with moderate upper extremity impairment. Twenty-four subjects at least 6-months post-stroke with a Fugl-Meyer upper limb score of 19 to 40 participated in this study. In the bilateral group (n=12), subjects practiced bilateral symmetrical activities, whereas the unilateral group (n=12) performed the same activity with the affected arm only [30]. The activities consisted of reaching-based tasks that were both rhythmic and discrete. Both groups received 1-hour sessions 3 times per week for 8 weeks (24 sessions). The Motor Assessment Scale (MAS), Motor Status Scale (MSS), and muscle strength were used as outcome measures. Assessments were administered at baseline and 1-week after the training was completed by a rater blinded to group assignment. Both groups improved on the MAS, MSS and measures of strength; however, the bilateral group had significantly greater improvement on the Upper Arm Function scale (a subscale of the MAS-Upper Limb Items). Thus both bilateral and unilateral training are efficacious in improving arm-hand function of moderately impaired chronic stroke survivors. Bilateral training may be more advantageous for proximal arm function.

Lower Limbs

One of the recurring requests of stroke patients is their ability to walk. Several strategies employed to achieve improved over-ground locomotion include, partial body-weight support treadmill, and a robot coupled with virtual environments to train the lower extremity (LE).

Effects of training with a robot-virtual reality system compared with a robot alone on the gait of individuals after stroke

This study tried to determine whether the transfer of training of LE movements to locomotion was greater using a virtual environment coupled with a robot or with the robot alone. In this single-blind, randomized clinical trial, 18 chronic stroke patients were enrolled in a 4-week training protocol. One group trained with the robot virtual reality (VR) (n=9) system and the other group trained with the robot alone (n=9) [31]. Outcome measures were walking speed, distance walked and the Patient Activity Monitor (PAM), a small accelerometer monitoring device worn around the ankle to monitor community ambulation. Greater changes in velocity and distance walked were demonstrated for the group trained with the robotic device coupled with the VR than training with the robot alone. Similarly, significant improvement in the distance walked and number of steps taken in the community were measured for the group that trained with robot coupled with the VR. These differences were maintained at 3 months' follow-up. The study concluded that LE training of individuals with chronic hemiparesis, using a robotic device coupled with VR, improved walking ability in both the laboratory and the community setting better than robot training alone.

Use of virtual reality to enhance balance and ambulation in chronic stroke: a double-blind, randomized controlled study

This study examined the effect of virtual reality on balance and gait function in patients with chronic hemiparetic stroke. Twenty-four adults with hemiparetic stroke for ≥12 months were randomly assigned to either an experimental group (n=12) or a control group (n=12). Both groups underwent conventional physical therapy, 40 minutes a day, 4 days a week for 4 wks [32]. The experimental group received an additional 30 minutes of virtual reality therapy which included stepping up/down, sharkbait, and snowboard. Balance performance was determined by the Balance Performance Monitor and Berg Balance Scale (BBS) tests. Gait performance was determined by the 10-m walking test, Modified Motor Assessment Scale (MMAS), and spatiotemporal parameters were obtained using GAITRite. In the balance test, the experimental group had improved BBS scores, balance and dynamic balance angles (ability to control weight shifting) compared with the controls ($P<0.05$). In the gait performance test, the experimental group showed significant improvements in velocity, MMAS scores, cadence, step time, step length, and stride length ($P<0.05$). Improvement in dynamic balance angles correlated with velocity and cadence ($P<0.01$). This study demonstrated that virtual reality augmented balance and associated locomotor recovery in adults with hemiparetic stroke, when added to conventional therapy. This study results should be interpreted with caution. In addition to the small number of patients enrolled, they were mildly affected by their stroke and were living independently in their community. Since the intervention group received additional 30-minutes of therapy compared to the controls it is difficult to say whether this improvement was due to the VR or due to this additional time period.

Multicenter randomized clinical trial evaluating the effectiveness of the lokomat in subacute stroke

This study compared the efficacy of robotic-assisted gait training (Lokomat) to conventional gait training in individuals with subacute stroke. Sixty three participants <6 months poststroke with an initial walking speed between 0.1 to 0.6 m/s completed the multicenter, randomized clinical trial. All participants received twenty-four 1-hour sessions of either Lokomat (n=33) or conventional (n=30) gait training [33]. Outcome measures were evaluated prior to training, after 12 and 24 sessions, and at a 3-month follow-up exam. Self-selected over-ground walking speed and distance walked in 6 minutes were the primary outcome measures, whereas secondary outcome measures included balance, mobility and function, cadence and symmetry, level of disability, and quality of life measures. Participants who received conventional gait training experienced significantly greater gains in walking speed (0.25±0.03 m/s *vs.* 0.12±0.03 m/s, $P=.002$) and distance (274±35.4 ft *vs.* 164.6±32.5 ft, $P=.03$) than those trained on the Lokomat (both tested immediately post-training). These differences were maintained at the 3-month follow-up evaluation. Secondary measures (Berg Balance Test, Functional Ambulation Category, NIH Stroke Scale, Motor Assessment Scale, Rivermead Mobility Index, Frenchay Activities Index and SF-36 Health Survey) were not different between the 2 groups, although a 2-fold greater improvement in cadence was observed in the conventional versus Lokomat group. Thus, in this study, conventional gait training intervention appeared to be more effective than robotic-assisted gait training for facilitating returns in walking ability for subacute stroke participants with moderate gait impairments.

Walking after stroke: what does treadmill training with body weight support add to over-ground gait training in patients early after stroke? A single-blind, randomized, controlled trial

This study assessed the effectiveness of gait training using body weight support on a treadmill compared with conventional gait training for people with subacute stroke who were unable to walk in a single-blind, randomized, controlled trial. Ninety-seven subjects were recruited within 6 weeks of their stroke onset and were randomly assigned to conventional rehabilitative treatment plus gait training with body weight support on a treadmill (PBWST; experimental group; n=52) or conventional treatment with over-ground gait training only (control group; n=45) [34]. All subjects received 60-minute sessions every weekday for 4 weeks (20-sessions) with a 6-month follow-up. Outcome measures were: Motricity Index, Trunk Control test, Barthel Index, Functional Ambulation Categories, 10-meter and 6-minute Walk Tests, and Walking Handicap Scale. Assessments were made at baseline, after 20 sessions of treatment, 2 weeks after treatment, and 6 months after stroke. After treatment, all patients were able to walk. Both groups showed improvement

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in all outcome measures (P<0.0063) at the end of the treatment and at follow-up. No differences were seen between the 2 groups before, during, and after treatment and at follow-up. Thus, in subacute patients with stroke, gait training on a body weight support treadmill was as effective as conventional gait training. The results of this study confirm the conclusion of prior case-control study that conventional over-ground training was as effective as PBWST and without the need for more personnel [34].

Short-form Tai Chi improves standing balance of people with chronic stroke

Four weeks of intensive Tai Chi practice has been shown to improve knee joint propioception and standing balance in healthy seniors [36]. This study set out to investigate whether short-form of Tai Chi could improve standing balance in patients with chronic stroke. One hundred thirty-six subjects >6 months after stroke were randomly assigned to a control group (n=62) practicing general exercises or a Tai Chi group (n=74) for 12 weeks of training [37]. Each week, 1 hour of group practice was supplemented by 3 hours of self-practice. A short-form of Tai Chi consisting of 12 exercises that require whole-body movements was performed in a continuous sequence. A blinded assessor examined subjects at baseline, 6 weeks (mid-program), 12 weeks (end-program), and 18 weeks (follow-up). The 3 outcome measures were (1) dynamic standing balance evaluated by the center of gravity (COG) excursion during self-initiated body leaning in 4 directions, (2) standing equilibrium evaluated in sensory challenged conditions, and (3) functional mobility assessed by Timed-up-and-go score. Compared to controls, the Tai Chi group showed greater COG excursion amplitude in leaning forward, backward, and toward the affected and nonaffected sides (P<.05), as well as faster reaction time in moving the COG toward the nonaffected side (P=.014) in the end-program and follow-up assessments. The Tai Chi group also demonstrated better reliance on vestibular integration for balance control at end-program (P=.038). However, neither group improved significantly their Timed-up-and-go scores. Twelve weeks of short-form Tai Chi produced specific standing balance improvements in people with chronic stroke that outlasted their 6 weeks training.

Does the use of TENS increase the effectiveness of exercise for improving walking after stroke? A randomized controlled clinical trial

This study investigated whether surface electrical stimulation can increase the effectiveness of task-related exercises for improving the walking capacity of patients with chronic stroke. This randomized, placebo-controlled clinical trial was conducted in a home-based program. One hundred and nine hemiparetic patients, at least 1 year post-stroke survivors were assigned randomly to either: (1) transcutaneous electrical nerve stimulation (TENS, n=28), (2) TENS + exercise (n=27), (3) placebo stimulation + exercise (n=25), or (4) control group (n=29) which received no active therapy [38]. The TENS group received 60 minutes of electrical stimulation at 100 Hz using a square pulse stimulator with electrodes placed at 4 acupuncture points on the lower limbs. The TENS + exercise group and placebo stimulation + exercise group received 60 minutes of exercises, after receiving 60 minutes of electrical and placebo stimulation respectively. Patients had baseline evaluation before treatment, after 2- and 4-weeks of treatment, and at follow-up four weeks after treatment ended. When compared with the other three groups, only the combined TENS + exercise group showed significantly greater absolute and percentage increases in gait velocity on GAITRite II walkway system (by 37.1–57.5%, all P<0.01), reduction in timed up and go scores (by –14.9 to –23.3%, P<0.01) and significantly more distance covered in the 6-minute walk test (by 22.2 to 34.7%, P<0.01) from week 2 onwards. The authors concluded that TENS can improve the effectiveness of a task-related exercise such as increasing walking capacity in hemiparetic stroke survivors. This conclusion should be accepted cautiously: i) their patient population was comprised of chronic stroke patients who could ambulate independently, ii) their control was a passive control, and iii) the combined TENS + exercise group had more intensive and additional duration of therapy.

Circuit-based rehabilitation improves gait endurance but not usual walking activity in chronic stroke: a randomized controlled trial

This study tried to determine whether benefits of strength training (circuit-based rehabilitation) could be translated to functional activities, such as an increase in the amount and rate that individuals with stroke can walk in their usual environments. This single-blind, randomized, controlled trial was carried out in a rehabilitation clinic. Sixty subjects (with a residual gait deficit at least 6 months post-stroke) were enrolled in the study. Two withdrew in the initial phase, leaving 58 participants (median age, 71.5 y; range, 39.0–89.0 y) who were randomized to the 2 intervention groups: the exercise group (n=31) received 12 sessions (30 minute sessions 3 times per week for 4-weeks) of clinic-based rehabilitation delivered in a circuit class designed to improve walking, or the control group (n=27) which received a comparable duration of group social and educational classes [39]. Each circuit station had a task-oriented gait or standing balance activity or muscle strengthening of lower limbs to improve gait. Results based on intention-to-treat analysis showed that the exercise group showed a significantly greater distance for the 6-minute timed walk test than the control group immediately after the intervention (P=.030) but that this effect was not retained 3 months later. The exercise and control groups had significantly different gait speed (P=.038) and scores on the Rivermead Mobility Index (P=.025) at the 3-month follow-up. The authors of the study concluded that circuit-based rehabilitation led to improvements in gait endurance but had no effect on the amount or rate of walking performance in usual environments. Clinical gains made by the exercise group initially were not maintained at 3 months follow-up.

MISCELLANEOUS

Additional exercises improve trunk performance after stroke: a pilot randomized controlled trial

Trunk control helps with sitting balance, and the ability to stand and walk; this is important to function independently. This study examined the effect of additional trunk exercises on trunk control after stroke. In this assessor-blinded, randomized, controlled trial, 33 inpatients in a stroke rehabilitation center were assigned to an experimental group (n=17) or a control group (n=16) [40]. In addition to conventional therapy, the experimental group received additional 10 hours of individual and supervised trunk exercises for 30 minutes, 4 times a week, for 5 weeks. Trunk performance was evaluated by the Trunk Impairment Scale (TIS) and its subscales of static and dynamic sitting balance and coordination. No significant differences were noted pretreatment between the 2 groups for the collected demographic variables, and primary outcome measures. After treatment, a significant improvement was seen in the experimental group compared to the control group for the dynamic sitting balance subscale, measuring selective lateral flexion initiated from the upper and lower part of the trunk, (P=.002, effect size=1.16). This study concluded that trunk exercises, in addition to conventional therapy, had a beneficial effect on the selective performance of lateral flexion of the trunk after stroke. The shortcomings of this study, in addition to the small sample size, were that it was difficult to judge whether this improvement was due to the intensity of therapy (10 additional hours of trunk exercises) or due to exercise themselves. Second, no mention was made whether this beneficial effect translated into improved functional outcome.

The effects of community-based rehabilitation on stroke patients in China: A single-blind, randomized controlled multicentre trial

This study evaluated the effects of a community-based rehabilitation therapy program on neurological functional deficit in sub-acute and chronic stroke patients. In this prospective, single-blind, multi-centre trial, 737 stroke patients residing in the community were randomized to 45 minute standardized community-based rehabilitation exercise program 3 times/week (n=377) or no additional exercise program (n=360) for 5 months [41]. The main outcome measure was the Clinical Neurological Function Deficit Scale (CNFDS) before intervention and at 2 and 5 months after treatment. Both groups improved over time, but the rehabilitation group showed significant improvement in CNFDS scores. After 5 months, the CNFDS scores for the cerebral infarction in the rehabilitation group improved by 6.77 *vs.* 1.57 points for the control group. Similarly, the CNFDS scores for cerebral hemorrhage in the rehabilitation group improved by 7.99 *vs.* 5.34 points for the control group. This implied a difference in improvement of 5.2 points in the cerebral infarction group and 2.65 points in the hemorrhage group. This study showed the beneficial effect of an ongoing standardized community-based exercise program to further improve the neurological function of stroke patients.

VISUAL

Comparing explorative saccade and flicker training in hemianopia: a randomized controlled study

Homonymous hemianopia (HH) occurs in 8.3% patient's post-stroke [42]. HH affects the patient's quality of life as they are unable to explore their spatial environment and undertake social activities. In this study explorative saccade training (EST) was compared with flicker-stimulation training (FT), to selectively improve saccadic behavior on the patients' blind side and benefit performance on natural exploratory tasks. Both these tasks were practiced on a computer screen placed 30 cms from patients eyes There were 30 hemianopic patients randomly assigned for 6 weeks to either EST (n=15) (a digit-search task) or FT (n=15) (blind-hemifield stimulation by flickering letters) [43]. Outcome variables (response times [RTs] during natural search, number of fixations during natural scene exploration, fixation stability, visual fields, and quality-of-life scores) were collected before, directly after, and 6 weeks after training. Patients assigned to EST group yielded a reduced (post/pre, 47%) digit-search RT for the blind side. Natural search RT decreased (post/pre, 23%) on the blind side but not on the seeing side. After FT, both sides RT remained unchanged. Only with EST did the number of fixations during natural scene exploration increase toward the blind and decrease on the seeing side (follow-up/pre difference, 238%). Even with the target located on the seeing side, more fixations occurred toward the blind side after EST. The EST group showed decreased (post/pre, 43%) fixation stability and increased (post/pre, 482%) asymmetry of fixations toward the blind side. Visual field size remained unchanged after both treatments. Patients in the EST group self-reported improvement in social domains. EST was able to selectively improve saccadic behavior, natural search, and scene exploration on the blind side due to scanning induced motor activity of eye movement. This activity was enhanced by repeated practice. These findings show substantial benefits of compensatory exploration training, including subjective improvements in mastering daily-life activities.

Visual neglect is characterized by failure to report, orient to, or respond to events in the contralesional space. It occurs in 23% of patient's post-stroke [44], has an increased incidence with right hemisphere stroke [45], and negatively impacts functional outcome [46].

Effectiveness of prism adaptation in neglect rehabilitation: a controlled trial study

This study investigated the effectiveness of a 2-week treatment comparing prism adaptation (PA) to an analogous visuomotor training performed without prisms, i.e., neutral pointing (NP) on visual neglect recovery. Twenty neglect patients were randomized to either PA group (n=10) or to NP group (n=10) for 10 daily sessions over a period of 2 weeks [47]. At the end of 2 weeks of NP treatment, the patients in the NP group also received PA treatment. Neglect was assessed before and after each treatment session and 1 month after the end of the PA treatment. Visuospatial abilities (pointing at a visual target with their right index finger) improved after both PA and NP treatment; however, the improvement was significantly higher in patients in the PA compared to patients in the NP group. Patients in the NP group who had PA training, further improved their visuospatial abilities up to the level reached by patients in the PA group (to non-pathological scores). The beneficial effects of PA persisted at 1 month from the end of treatment. The study concluded that leftward recalibration of sensorimotor reference frames induced by PA was effective in obtaining neglect recovery, although visuomotor training based on pointing partially improved neglect symptoms.

Hemispatial neglect and rehabilitation in acute stroke (AVERT Study)

This study compared 2 methods of determining neglect in patients within 2 days of stroke, and to investigate whether early neglect affected rehabilitation practice, and whether

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this relationship could be modified by an early, intensive mobilization intervention. Seventy one stroke patients admitted to an acute hospital stroke unit with modified Rankin Scale (mRS) score of ≤3, were randomized to either very early mobilization (VEM, n=38) or to standard care (SC, n=33) [48]. VEM implied mobilization as soon as practical after recruitment preferably within 24 hours of stroke symptom onset. Neglect was determined using the Star Cancellation Test and the National Institutes of Health Stroke Scale (NIHSS) inattention item within 48 hours of stroke onset. Assessing neglect acutely within 2 days after stroke was difficult: 29 of the 71 patients were unable to complete the Star Cancellation Test. Level of agreement between this test and the NIHSS measure was fair to moderate (0.42). Presence of neglect did not prevent early mobilization. SC group patients with neglect had longer hospital stays (median, 11d) than those without neglect (median, 4d); however, there was no difference in length of stay between patients with and without neglect in the VEM group (median, 6d in both). Post-stroke patients with neglect irrespective of the group were less likely to return home. Eighty-seven percent post-stroke patients with neglect irrespective of the group had poor outcome as measured by the mRS at 12 months, compared to 45% of patients without neglect. This study showed early mobilization of patients with neglect was feasible and can contribute to a shorter acute hospital length of stay for the same amount of daily therapy.

A computerized visual perception rehabilitation programme with interactive computer interface using motion tracking technology – a randomized controlled, single-blinded, pilot clinical trial study

This study assessed the effectiveness of a computerized visual perception rehabilitation program using motion tracking technology for visual perception impairment. In this randomized controlled, single-blinded, pilot clinical trial in an inpatient rehabilitation hospital, 16 left hemiplegic patients with visual perceptional impairment were randomly assigned to receive either (1) participation in a computerized visual perception rehabilitation program with an interactive patient-computer interface applying motion tracking technology (CAMSHIFT) algorithm, or (2) use of the PSS CogRehab (Psychological Software Service, US) program for 3 sessions per week, 30 minutes per session for 4-weeks. There were 8 patients in each group [49]. The main measures were: Mini-Mental Status Examination, Motor-free Visual Perception Test and Modified Barthel Index were assessed at the beginning and end of the training. After training, the mean ±SD Motor-free Visual Perception Test score increased significantly in both experimental (from 65.8±19.5 to 77.8±28.7) and control group (from 68.3±11.4 to 74.1±14.8) (P<0.01). Modified Barthel Index score also increased significantly in both groups, with the experimental group recording a higher increase. In this study, computerized visual perception rehabilitation program with interactive computer interface using motion tracking technology was beneficial to help improve stroke patient's visual perception impairment.

Mirror therapy in complex regional pain syndrome type 1 of the upper limb in stroke patients

In this trial, the effectiveness of mirror therapy on Complex regional pain syndrome type 1 (CRPSt1) of the upper limb was studied. CRPSt1is a painful and debilitating condition, frequently found after stroke, ranging from prevalence 1.5% to 61% depending on how it is defined [50]. CRPSt1 interferes with the rehabilitative process and outcome, and has limited treatment options. In this randomized controlled study, of the 208 patients with first episode of unilateral stroke admitted to the rehabilitation center, 48 patients with CRPSt1 of the affected upper limb were assigned to either a mirror therapy group (n=24) or placebo control group (n=24) in addition to their conventional rehabilitation program [51]. The mirror group received additional 30 minutes of mirror therapy per session for the first two weeks and a 1 hour of mirror therapy per session in the next two weeks. The control group performed the same exercises for the same duration with the reflecting side of the mirror covered. The mean scores of both the primary end points (reduction in the visual analogue scale score of pain at rest, on movement, and brush-induced tactile allodynia) and secondary end points (Wolf Motor Function Test and Motor Activity Log) significantly improved in the mirror group (P<.001). There was no significant improvement observed in any of the control group values (P>.001). This significant difference after treatment (P<.001) was maintained at the 6-month follow-up in the mirror compared to the control group. The results of this study indicate that mirror therapy effectively reduced pain and enhanced upper limb motor function in stroke patients with upper limb CRPSt1. The study main limitations included its small sample size and the CRPSt1 incidence rate of 23. This high rate begs the question of how CRPSt1 is defined.

Cognition

Reducing attention deficits after stroke using attention process training: A randomized controlled trial

Cognitive deficits occur in 65% of patients after stroke [52]. Impaired attention contributes to poor stroke outcomes. Attention process training (APT) has been found to reduce attention deficits after traumatic brain injury [53]. This trial evaluated effectiveness of APT in improving attention plus broader outcomes, in stroke survivors 6 months after stroke. APT is a theoretically based, hierarchical, multi-level treatment addressing sustained, selective, alternating and divided attention, and can be easily administered by rehabilitation team members. In this prospective, single-blinded, randomized, clinical trial there were, 78 stroke survivors admitted over 18 months and identified via neuropsychological assessment (Bell's Test, Trail Making Test A & B, Integrated Visual Auditory Continuous Performance Test Full-Scale Attention Quotient [IVA-CPT], and Paced Auditory Serial Addition Test [PASAT]) as having attention deficit. Participants were randomly allocated to standard care plus individualized APT for 1 hour daily for 4 weeks (n=38) up to 30 hours, or standard care alone (n=40) [54]. Both groups were impaired (z ≤–2.0) across measures of attention at baseline, with the exception of PASAT, which was below average (z ≤–1.0). The primary outcome was IVA-CPT assessed at 5 weeks and 6 months after randomization. IVA-CPT is a computerized continuous performance test where the subject clicks the button each time they see or hear the number 1. APT resulted in a significantly greater (P<0.01) improvement on the primary outcome than standard care. Difference in change on the

Cognitive Failures Questionnaire approached significance (P=0.07). Differences on other measures of attention and broader outcomes were not significant. Thus APT was found to be a viable and effective means of improving attention deficits after incident stroke.

Efficacy of time pressure management in stroke patients with slowed information processing: a randomized controlled trial

Mental slowness is a common complaint after stroke [55]. This leaves the patients tired, angry, and frustrated. This study examined the effects of a Time Pressure Management (TPM) strategy taught to stroke patients with mental slowness, compared to the effects of usual care in a randomized controlled trial. TPM uses cognitive strategies to "prevent" or to "manage" time pressure while trying to complete a task. It is a compensatory rather than a restorative strategy [56]. Thirty seven patients who had sustained a stroke 3 months earlier and were undergoing rehabilitation were assigned to either TPM (n=20) or to the usual care which was comprised of stroke education (n=17) [57]. Both groups received 10 hours of treatment for mental slowness in real-life tasks. The main outcome measures were: Mental Slowness Observation Test and Mental Slowness Questionnaire administered at baseline, at the end of treatment (at 5–10 wk) and at 3 months. Both groups had a significant decline in number of complaints on the Mental Slowness Questionnaire. This decline was present at 3 months. At 3 months, the TPM group had a significant increase in the speed of performance on the Mental Slowness Observation Test compared to the usual-care group (t=–2.7, P=.01). Thus at the 3 month follow-up both groups showed fewer complaints, but the TPM group showed improved speed of performance on everyday tasks. The authors concluded that TPM treatment is an effective tool for treating stroke patients with mental slowness. However; the small sample size, using young patients with high Barthel Index scores (ADL-independent) make the conclusion of this study less generalizable.

Aerobic exercise improves cognition and motor function poststroke

Cognitive deficits (CD) occur in 12% to 56% of patient's post-stroke [58]. Patient's with CD are often restricted and even denied access to rehabilitation services; this lack of care impedes their recovery [59]. Aerobic exercise (AEX) has been shown to improve cognitive executive function (EF) processing in healthy individuals. This study evaluated whether AEX could improve EF processing in patients after stroke. Thirty-eight chronic stroke survivors, after cardio-respiratory testing were randomized to 2 either AEX group (n=19, performed progressive resistive stationary bicycle training at 70% maximal heart rate) or to the Stretching Exercise (SE) group (n=19, performed stretches at home). Both groups exercised 3 times a week (45-minute sessions) for 8 weeks [60]. Between-group comparisons were performed on the change in performance at "Post" (8 weeks later) and "Retention" (16 weeks later) for neuropsychological and motor function measures. The VO(2)max, serial reaction time task (SRTT; i.e., "procedural motor learning") and information processing speed significantly improved at Post with AEX (p<.05). AEX also improved predictive force accuracy for a precision grip task requiring attention and conditional motor learning of visual cues. Ambulation and sit-to-stand transfers were significantly faster in the AEX group at Post (p<.038), with balance control significantly improved at Retention (p<.041). EF measurements were the same between the 2 groups. In this study AEX improved mobility and cognitive EF processing speed. Its main limitation was the small sample size.

A summary of these RCTs in Stroke Rehabilitation in 2009 is presented in Table 1.

Conclusions

The following conclusions can be drawn from these RCTs (Level 1 evidence) despite some of these studies being small: 1) the constraint induced movement therapy (CIT), regularly used in chronic stroke patients and found to be effective, when used in acute stroke patients at ≤4weeks was as effective as controls. However, intensive CIT did not lead to motor improvement in arm-hand function [21]; 2) therapist provided exercise programs (when self-administered by patients during their off-therapy time in a rehabilitation setting) do improve arm-hand function [24]; 3) robotic arm treatment helped decrease motor impairment and improved function in chronic stroke patients only [25]; 4) robotic locomotor trainer (locomat) and body-weight support treadmill are no more effective in improving patient's ability to walk than therapist assisted over-ground locomotor training [33]; 5) Tai Chi exercises do help improve balance and weight bearing [37]; 6) exercise programs for community dwelling stroke patient helped maintain and even improve their neurological functional state [41]; 7) use of prisms and computerized motion tracking and saccadic exercises are increasingly been used in visual rehabilitation of patients with visual neglect and homonymous hemianopsia [47]; 8) cognitive rehabilitation and aerobic exercises are used to help stroke patients with attention deficit and mental slowness [54].

Appendix 1 – Keywords and Search Limits used

Randomized Controlled trials
RCT
Rehabilitation OR neurorehabilitation
Motor recovery OR functional recovery
Stroke OR cerebrovascular disorders OR CVA
Arm OR arm-hand OR upper extremity
Leg OR lower extremity
Constraint induced Therapy OR CIT OR CIMT
Robot OR Robotic, non-robotic devices
Functional Electrical stimulation OR stimulation
Exercises
Partial body-weight support treadmill
Mirror therapy
Mental imagery
Prism OR Patching
Limits: Human
Adult (age >19 years)
English language
Publication date: 1/1/2009 to 12/31/2009

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Table 1. A summary of the RCTs in Stroke Rehabilitation in 2009.

References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
			Arms and Hand		
Dohle et al. [5]	≤8 weeks post-stroke	Acute Rehabilitation Hospital	36; Mirror therapy (MT)=18 Control=18	MT *vs.* control for 30 minutes a day, 5 days a week for 6 weeks	MT patients regained more distal function than controls. MT also improved recovery of surface sensation and hemineglect. These improvements were independent of the side of the lesioned hemisphere.
Liu et al. [7]	≥7 days post-stroke	Acute hospitalization	35; Mental Imagery (MI)=18 Control=17	The MI intervention was standardized practices and daily tasks broken down into chunking-self regulation-mental rehearsal strategies or control (functional rehabilitation) for 15 1 hour daily session for 3-week.	The MI patients showed better performances on 4 of 5 trained tasks *vs.* only 1 of 5 task in the FR patients (P=0.021). The MI patients also outperformed their FR counterpart on the 3 of 5 trained and 2 of 3 untrained tasks carried out in the novel environment. Thus MI imagery improved patients' ability on performing the tasks they did not previously train on and in places different from the training environment.
Mangold et al. [10]			23; Functional Electrical Stimulation (FES)=12 Control=11	FES or control 12 sessions over 4 weeks.	The EBI and CMSA arm score improved in both groups. The CMSA hand function and resistance to passive movement of finger and wrist flexors improved significantly in the FES group. Shoulder pain and gains on outcome measures were the same between the groups.
Chan et al. [11]	≥6 months post-stroke		20; FES=10 Control=10	15 training sessions comprising of Each session consisted of stretching activities (10 minutes), occupational therapy treatment (60 minutes), and FES with bilateral tasks (20 minutes) or sham FES.	After 15 training sessions, the FES group had significant improvement in FMA (P=.039), FTHUE (P=.001), and active range of motion of wrist extension (P=.020) compared to the control group.
Klaiput et al. [12]	≤6 months post-stroke		20; Electrical stimulation = 10 Control = 10	2 hour session of simultaneous electrical stimulation over the median and ulnar nerves at the wrist *vs.* sham-stimulation (control).	Lateral and tip pinch strength increased in both groups (P<.05). However; increase in the pinch strength was greater in the peripheral sensory stimulation than the sham-control group (P<.05). The change Action Research Arm Test score was same in both groups (P>.05).
Chae et al. [13]	≥12 weeks post-stroke	Out-patient setting	26; Electrical stimulation=13, Control=13	ES was 12 Hz *vs.* control 1 Hz 1 hour/day for 6weeks followed by 18 hours of task specific training.	There was no treatment or time by treatment interaction effects for any of the outcome measures (primary-Fugl-Meyer Motor Assessment; secondary-Arm Motor Ability Test and delay and termination of EMG activity) at baseline, at the end of ES and task specific training, and at 1, 3, and 6 months follow-up between the 2 groups.
Lin et al. [17]	6 to 40 months after stroke onset (mean 15 months)	Out-patient setting	32; Constraint Induced Therapy (CIT)=16 Control=16	CIT for 2 hours daily 5 days per week for 3 weeks and restraint of the unaffected hand for 5 hours outside of the rehabilitation training) or a conventional intervention with hand restraint for the same duration.	CIT group exhibited better performance in motor function, level of functional independence, mobility, extended activities during daily life, and health-related quality of life after treatment as measured by Fugl-Meyer Assessment, Functional Independence Measure, Motor Activity Log, Nottingham Extended Activities of Daily Living Scale, and Stroke Impact Scale.

References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
Lin et al. [18]	≥6 months post-stroke	Out-patient setting	60; CIT=20 BA =20 Control=20	Each group received intensive training for 2 hours/day, 5 days/week, for 3 weeks.	The BAT group exhibited greater gains in the proximal part of the FMA score than the modified CIT and control groups. Enhanced performance was found for the modified CIT group in the MAL, the FIM motor-subscale, and ADL/IADL of the SIS.
Woodbury [19]	≥3 months	Out-patient setting	11; Trunk restraint (TR)=6 No restraint (NR)=5	CIT for all enrolled patients (mitt on the unaffected hand for 90% of waking hours over 14 days and participated in 10 days/6 hours/day of supervised practice with TR or NR.	Both groups gained functional arm ability (P<.05 all tests). Post-training, the TR group had straighter reach trajectories (P=.000) and less trunk displacement (P=.001). The TR group gained shoulder flexion (P=.006) and elbow extension (P=.022) voluntary ranges of motion compared to the NR group.
Dromerick et al. [21]	≤14 days post-stroke	Acute hospital	52; CIT (n=35; low intensity=19, high intensity=16), Control (n=17)	The low intensity CIT group received 2 hours of shaping therapy/day and wore mittens for 6 hours/ day; high intensity CIT group received 3 hours of shaping therapy/day and wore mittens for 90% waking hours. The control group received compensatory techniques for ADLs, range of motion and strengthening. Both groups received 2 weeks of study-related treatments.	Both groups improved with time on the total ARAT score. There was a significant time x group interaction (F=3.1, p<0.01), such that the high intensity CIT group had less improvement at day 90. No significant differences were found between the dose-matched CIT and control groups at day 90. Head MRI showed no evidence of activity-dependent lesion enlargement.
Hammer et al. [22]			30; Forced use=15 Control=15	Both group of patients received in 2-weeks of daily training on weekdays. In addition, the forced use group wore a restraining sling on the non-paretic arm for 6 hours/weekday.	The forced use group achieved greater improvements immediately post-intervention, but this was not significant. At 3-month follow-up both groups achieved 1.0 score point on both scales of the Motor Activity Log.
Harris et al. [24]	≤2 weeks post-stroke	Acute rehabilitation unit	103; GRASP=53 Control=50	GRASP group included exercises aiming for arm and hand strengthening, range of movement, gross and fines motor skills, and task oriented activities of daily living *vs.* Control included stroke and health education for 1 hour daily 6-days per week for 4-weeks.	The GRASP group showed greater improvement in upper limb function (CAHAI) compared to the control group (P<0.001). The GRASP group maintained this improvement at 5 months post-stroke. There was significant improvement in favor of the GRASP protocol for grip strength and paretic upper limb use. No serious adverse effects were experienced.
Housman et al. [25]	≥6 months post-stroke	Outpatient setting	28; T-WREX=14 Control=14	T-WREX a passive arm orthosis *vs.* table-top exercise treatment for 24 1-hour treatment sessions (3 times per week for 8 weeks).	All subjects significantly improved upper extremity motor control (Fugl-Meyer), active reaching range of motion (ROM), and self-reported quality and amount of arm use (Motor Activity Log) (P≤0.05). Improvements were maintained at 6 months. The T-WREX group maintained gains on the Fugl-Meyer better than controls at 6 months (P=0.04). Subjects reported a preference for T-WREX training.

References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
Hu et al. [25]	≥6 months post-stroke	Outpatient setting	27; Continuous electromyography (EMG)-driven robot (interactive group, n=15) Passive motion device (passive group, n=12)	20-session wrist training with a continuous electromyography (EMG)-driven robot (interactive group) or a passive motion device (passive group) completed within 7 consecutive weeks.	Significant improvements in Fugl-Meyer Assessment scores (shoulder/elbow) were found in the interactive group (P<.05). Significant decreases in the Modified Ashworth Scale (MAS) scores were observed in the wrist and elbow joints for the interactive group and in the wrist joint for the passive group (P<.05). These MAS changes were associated with the decrease in EMG activation level of the flexor carpi radialis and the biceps brachii for the interactive group (P <.05). However, both robot groups had no effect on the ARAT and FIM scores (p≥0.5).
Ellis et al. [27]		Outpatient setting	14; Experimental group=7, Control group=7	The experimental group received a total of 3 sessions/ week over an 8-week period with a progressive increase by 25% of arm weight actively supported by the participant while reaching to various outward targets. The control group practiced the same reaching tasks with matched frequency and duration with the weight of the arm supported.	Change scores for work area at 9 different loads were larger for the experimental group at the limb-loading levels of 50%, 100%, 125% and 175% (p≤0.05) Thus progressive shoulder abduction loads helped reach ROM against gravity.
Lakse et al. [28]	≥2 months post-stroke	In-patient rehabilitation setting	38; Injection group=21 Control group=17	Injection was a mixture of 1 ml triamcinolone and 9 ml of prilocain vs. no injection. Both groups received conventional therapy plus TENS.	The range of shoulder motion and shoulder pain scores improved in both group of patients, however; improvement was more significant in the injection group. Barthel scores improved equally in both groups. Changes in the Brunnstrom upper-extremity and modified Ashworth scores between both groups was similar.
Kim et al. [29]	≥3 months post-stroke		10; tDCS=5, Sham=5	1 mA of tDCS for 20 mins *vs*. sham for 30 secs	Finger acceleration measurement and Box and Block test improved after anodal tDCS compared with sham stimulation (P<0.05). This improvement lasted for 30 minutes for the finger acceleration measurement and 60 minutes for the Box and Block test (P<0.05) with no effect on attention and fatigue.
Stoykov et al. [30]	≥6 months post-stroke		24; Bilateral group=12 Unilateral=12	Bilateral group subjects practiced bilateral symmetrical activities, whereas the unilateral group performed the same activity with the affected arm only. The activities consisted of reaching-based tasks that were both rhythmic and discrete. Both groups received 1-hour session 3 times per week for 8 weeks (24 sessions).	Both groups improved on the MAS, MSS and measures of strength, however; the bilateral group had greater improvement on the Upper Arm Function scale (a subscale of the MAS-Upper Limb Items).

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References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
			Legs		
Mirelman et al. [31]			18; Robot virtual reality (VR)=9 Robot alone=9	for 4-weeks	Greater changes in velocity and distance walked were demonstrated for the group trained with the robotic device coupled with the VR than training with the robot alone. Similar improvements in the distance walked and number of steps taken in the community were for the robot coupled with the VR group. These differences were maintained at 3 months' follow-up.
Kim et al. [32]	≥12 months post-stroke		24; Virtual Reality (VR)=12, Control group=12	40 minutes a day, 4 days a week for 4 wks of conventional therapy plus 30 minutes of additional VR or no therapy (control).	In the balance test, the VR group had improved Berg Balance Scale scores, balance and dynamic balance angles (ability to control weight shifting) compared with the controls ($P<0.05$). In the gait performance test, the VR group showed improvements in velocity, Modified Motor Assessment Scale scores, cadence, step time, step length, and stride length ($P<0.05$).
Hidler et al. [33]	<6 months post-stroke		63; Lokomat=33 Conventional=30	24 1-hour sessions of either Lokomat or conventional gait training.	Participants who received conventional gait training experienced greater gains in walking speed (0.25±0.03 m/s *vs.* 0.12±0.03 m/s, P=.002) and distance (274±35.4 ft *vs.* 164.6±32.5 ft, P=.03) than those trained on the Lokomat both immediately post-training and at the 3-month follow-up evaluation.
Franceschini et al. [34]	<6 weeks post-stroke	Acute rehabilitation unit	97; Partial body weight support treadmill =52 Conventional over-ground gait training=45	Partial body weight support on a treadmill *vs.* conventional over-ground gait training.	Both groups showed improvement in all outcome measures ($P<0.0063$) at the end of the treatment and at follow-up. After treatment, all patients were able to walk.
Au-Yeung et al. [37]	>6 months post-stroke	Community setting	136; Tai Chi group=74 Control group=62	Short form Tai Chi exercises *vs*. control group practicing general exercises for 12 weeks. Each week, 1 hour of group practice supplemented by 3 hours of self-practice.	The Tai Chi group showed greater COG excursion amplitude in leaning forward, backward, and toward the affected and non-affected sides (P<.05). Faster reaction time in moving the COG toward the non-affected side (P=.014) in the end-program and follow-up assessments compared to controls. Neither group improved in Timed-up-and-go scores.
Ng et al. [38]	1 year post-stroke	Community setting	109; (1) transcutaneous electrical nerve stimulation (TENS, n=28), 2) TENS + exercise (n=27), (3) placebo stimulation + exercise (n=25), (4) control group (n=29)	TENS group received 60 minutes of electrical stimulation at 100 Hz using a square pulse stimulator with electrodes placed at 4 acupuncture points on the lower limbs. The TENS + exercise group and placebo stimulation + exercise group received 60 minutes of exercises, after receiving 60 minutes of electrical and placebo stimulation respectively.	Combined TENS + exercise group showed greater absolute and percentage increases in gait velocity on GAITRite II walkway system ($P<0.01$), reduction in timed up and go scores ($P<0.01$) and more distance covered in the 6-minute walk test ($P<0.01$) from week 2 onwards.

References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
Mudge et al. [39]	6 months post-stroke	Out-patient clinic	60; Exercise group=31, Control group=27	Exercise group had 12 sessions (30 minutes 3 times per week for 4-weeks) in clinic-based rehabilitation delivered in a circuit class designed to improve walking or the control group received a comparable duration of group social and educational classes.	Exercise group covered greater distance for the 6-minute timed walk test than the control group immediately after the intervention (P=.030) but that this effect was not retained 3 months later. The exercise and control groups had different gait speed (P=.038) and scores on the Rivermead Mobility Index (P=.025) at the 3-month follow-up.
Miscellaneous					
Verheyden et al. [40]			33; Experimental group=17 Control=16	Experimental group received additional 10 hours of individual and supervised trunk exercises for 30 minutes, 4 times a week, for 5 weeks.	Post-treatment, there was a improvement in the experimental compared to the control group for the dynamic sitting balance subscale and for the selective lateral flexion initiated from the upper and lower part of the trunk, (P=.002, effect size=1.16). The study concluded that trunk exercises in addition to conventional therapy, improved sitting balance and selective trunk movements.
Jianjun et al. [41]		Community based	737; Exercise=377 No exercise=360	45 minute standardized community-based exercise program 3 times per week *vs.* no additional exercise for 5 months.	After 5-months, the CNFDS scores for the cerebral infarction in the rehabilitation group improved by 6.77 *vs.* 1.57 for the control group. Similarly, the CNFDS scores for hemorrhage in the rehabilitation group were 7.99 *vs.* 5.34 for the control group. This implied a difference in improvement of 5.2 in the cerebral infarction and 2.65 in the hemorrhage groups. This study showed the beneficial effect of an ongoing standardized community-based exercise program to further improve the neurological function of stroke patients.
Roth et al. [43]			30; Explorative Saccade Training (EST)=15 Flicker Stimulation Training (FT)=15	Either EST, a digit-search task or FT, blind-hemifield stimulation by flickering letters on a computer screen for 6 weeks.	Patient's assigned to EST group had a reduced (post/pre, 47%) digit-search response time (RT) for the blind side and (post/pre, 23%) reduced natural search RT on the blind side. After FT, both sides RT remained same. Only patients in the EST group increased the number of fixations during natural scene exploration toward the blind and decrease on the seeing side (follow-up/pre difference, 238%). Visual field size remained unchanged after both treatments. Patient's in the EST group self-reported improvement in social domains.
Serino et al. [47]			20; Prism adaptation (PA)=10 Without prisms, i.e., neutral pointing (NP)=10	Prism adaptation (PA) compared to visuomotor training without prisms, i.e., neutral pointing (NP) 10 daily sessions over a 2 week period.	Visuo-spatial abilities (pointing at a visual target with their right index finger) improved after both PA and NP treatment; however, the improvement was greater in the patients in the PA than in the patients in the NP group. Patients in the NP group submitted to PA, improved to the level reached by patients in the PA group, i.e., to non-pathological scores. This beneficial effects of PA persisted a 1 month from the end of treatment.

References	Time to randomization post-stroke	Set-up	Sample size (#)	Interventions	Main findings
Cumming et al. [48]	≤2 days of their acute stroke	Acute hospital stroke unit	71; Very early mobilization (VEM)=38 Standard care (SC)=33	VEM (implied initial mobilization as soon as practical after recruitment preferably within 24 hours of stroke symptom onset) *vs.* SC.	SC group patients with neglect had longer hospital stays (median, 11d) than those without neglect (median, 4d); however, there was no difference in length of stay between patients with and without neglect in the VEM group (median, 6d in both). Post-stroke patients with neglect were less likely to return home. 87% post-stroke patients with neglect had poor outcome as measured by the mRS at 12 months compared to 45% of patients without neglect.
Si Hyun Kang et al. [49]			16; Computer interface with motion tracking technology (CAMSHIFT)=8 Psychological Software Service (PSS) CogRehab program=8	CAMSHIFT *vs*. PSS CogRehab program for 3 sessions per week, 30 minutes per session for 4-weeks.	After training, the mean (SD) Motor-free Visual Perception Test score increased in both experimental (from 65.8 (19.5) to 77.8 (28.7)) and control groups (from 68.3 (11.4) to 74.1 (14.8)) (P<0.01). Modified Barthel Index score increased in both groups, with the experimental group recording a higher increase.
Cacchio et al. [51]	>3 months post-stroke	Rehabilitation center	48; Mirror therapy=24 Placebo control group=24	30 minutes of Mirror therapy in the first 2-weeks followed by 1-hr per week for next 2-weeks *vs.* controls, who performed the same exercises for the same duration with the reflecting side of the mirror covered	The mean scores of both the primary end points (reduction in the visual analogue scale score of pain at rest, on movement, and brush-induced tactile allodynia) and secondary end points (Wolf Motor Function Test and Motor Activity Log) improved in the mirror group (P<.001). No improvement was observed in any of the control group values (P>.001). This difference after treatment (P<.001) was maintained at the 6-month follow-up in the mirror compared to the control group.
Barker-Collo et al. [54]	18 months post-stroke	Out-patient setting	78; APT=38, Standard care alone=40	APT for 1 hour daily for 4 weeks up to 30 hours or standard care alone.	APT resulted in a greater improvement on the primary outcome than standard care (P<0.01). Change on the Cognitive Failures Questionnaire showed a trend (P=0.07) favoring the APT group.
Winkens et al. [57]	>3 months post-stroke	Rehabilitation Center (both in-patient and out-patient setting)	37; TPM=20, Control=17	10 hours of TPM treatment *vs.* stroke education	Both groups showed decline in the number of complaints on the Mental Slowness Questionnaire. This decline was present at 3 months. At 3 months, speed of performance on the Mental Slowness Observation Test was higher in the TPM group compared to the usual-care group (P=.01).
Quaney et al. [60]	>6 months post-stroke		38; Aerobic Exercise (AEX) group=19), Stretching Exercise (SE) group=19)	AEX group performed progressive resistive stationary bicycle training at 70% maximal heart rate and the SE group performed stretches at home. Both groups exercised 3 times a week (45-minute sessions) for 8 weeks.	The VO(2)max, serial reaction time task ("procedural motor learning") and information processing speed improved at "Post" with AEX (p<.05). AEX also improved predictive force accuracy for a precision grip task requiring attention and conditional motor learning of visual cues. Ambulation and sit-to-stand transfers were faster in the AEX group at "Post" (p<.038), with balance control significantly improved at "Retention" (p<.041). EF measurements were the same between the 2 groups. AEX improved mobility and cognitive EF processing speed.

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