DOI: 10.5935/0104-7795.20120011

Chronic cerebral vascular accident: rehabilitation

Authorship: Associação Brasileira de Medicina Física e Reabilitação
Conclusion: July 1, 2011

Participants: Thaís Tavares Terranova, Fabiola Olea Albieri, Munique Dias de Almeida, Denise Vianna Machado Ayres, Sissi Farrardo da Cruz, Mariana Vita Milazzotto, Denise Rodrigues Tsukimoto, Marta Imamura, Linamara Rizzo Battistella

DESCRIPTION OF THE EVIDENCE COLLECTION METHOD

This study revised articles from the MEDLINE (PubMed) databases and other research sources, with no time limit. To do so, the search strategy adopted was based on (P.I.C.O.) structured questions (from the initials "Patient"; "Intervention"; "Control" and "Outcome". As keywords were used: (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism and thrombosis) AND exercise therapy AND upper extremity; (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism and thrombosis) AND restraint induced therapy; stroke AND exercise therapy AND upper extremity; *(intracranial arteriosclerosis OR intracranial embolism and thrombosis OR stroke OR cerebrovascular disorders) AND electric stimulation therapy AND upper extremity; (intracranial arteriosclerosis OR intracranial embolism and thrombosis OR stroke OR cerebrovascular disorders) AND (orthotic devices OR splints) AND upper extremity;knowledge of Results OR biofeedback OR electromyography AND stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism and thrombosis AND rehabilitation; stroke AND upper extremity AND functional laterality; stroke AND upper extremity AND robotics AND physical therapy modalities; stroke AND body weight supports treadmill training AND floor walking; stroke AND gait disorders AND (treadmill exercises OR floor walking); stroke AND postural balance AND physical therapy modalities; stroke AND postural balance AND feedback, sensory; (stroke OR hemiplegia) AND gait disorders, neurologic AND orthotic devices; (stroke OR hemiplegia) AND gait disorders, neurologic AND (feedback, sensory OR proprioception). stroke AND (TENS OR transcutaneous electric stimulation); (stroke OR hemiplegic) AND electric stimulation therapy AND muscle spasticity; hemiplegic AND electric stimulation therapy AND spasticity; stroke AND (virtual reality OR wii game); (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism OR thrombosis) AND resistance training AND recovery function; stroke AND biofeedback, psychology AND Electromyography AND gait; (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism and thrombosis) AND biofeedback, psychology AND (gait OR gait disorders, neurologic).*

With the above keywords crossings were performed according to the proposed theme in each topic of the (P.I.C.O.) questions. After analyzing this material, articles regarding the questions were selected and, by studying those, the evidences that fundamented the directives of this document were established.

LEVEL OF RECOMMENDATION AND EVIDENCE:

A: Strong consistency experimental or observational studies.

B: Fair consistency experimental or observational studies.

C: Case reports (uncontrolled studies).

D: Opinion lacking critical evaluation, based on consensus, physiological studies or animal models.

OBJECTIVES:

Offering information regarding treatment and rehabilitation of patients suffering from encephalic vascular accident in chronic stage, i.e., EVA time longer than three months.

CONFLICTS OF INTERESTS:

There are no declared conflicts of interests.

INTRODUCTION

The World Health Organization defines encephalic vascular accident, EVA, as a rapid onset clinical syndrome, which leads to a focal cerebral damage of vascular origin, with duration longer than twenty-four hours. Studies regarding this prevalence estimate that there are about 5 to 10 cases/1000 inhabitants, worldwide, revealing an estimate of surviving cases in EVA patients. It is expected that, approximately, 60% of survivors recover independence for self care and 75% recover independent gait, and 20% will require institutional care. Frequently, the cerebral lesion caused by EVA leads to disabilities, which are problems related to body functions and structures such as organs, limbs and their components. As a consequence, such disabilities may generate difficulties in the performance of activities, as well as restrictions in participation, those related to problems that an individual may face by getting involved in life situations.

Based on the above, the rehabilitation process is fundamental in minimizing the impact of cerebral lesion on the patient's quality of life.

The changes in muscle tone, strength, movement amplitude of UULL and LLLL, activities of daily life and gait capacity must be considered. In the preparation of the treatment program it is necessary to focus in the global functional recovery. Therefore, the purpose of this directive is to expose the different types of treatment, typically used in the rehabilitation of post-EVA patients in chronic phase.

THERAPEUTIC SESSION

Functional recovery of hemiplegic upper limb

1. Is constraint-induced movement therapy effective in the functional recovery of hemiplegic upper limbs of patients with encephalic vascular accidents in chronic phase?

The use of constraint-induced movement therapy for the functional recovery of hemiplegic upper limb, applied to pacients that suffered only one episode of EVA, between three to nine months, performed for a period of fourteen days with the constraint of the unaffected upper limb in 90% of the waking hours and six hours of standardized and directed therapy, promotes a significant improvement of the hemiplegic upper limb's motor skills and function, both on the post-treatment period, 12.55%, and on the follow-up period after twelve months, 13.09%, demonstrated by results obtained from the application of the Wolf Motor Function Test/Functional Ability scale, from zero to five points.

By the Motor Activity Log (MAL) scale, zero to five points, it is demonstrated that the constraint-induced movement therapy provides improvements both in the quantity of use scale and in the quality of movement of the hemiplegic upper limb in the post-treatment periods, 42.91% and 41.93%, respectively, and after twelve months, 43.19% and 43.49%, respectively.

On the Stroke Impact Scale, there is a 69.39% improvement in hand function control, self perception of the difficulty related to hand function, on this scale after twelve months with constraint-induced movement therapy[1] **(A)**.

Among patients that suffered EVA, in average 12.25 months after the episode, the constraint-induced movement therapy applied for two hours a day, five days a week, during a period of three consecutive weeks and unnafected limb constraint for six hours a day, improves in 23.80% the kinematic *performance* (time) for the reaching movement with paretic upper limb ($p = 0.005$).

There is also improvement in the affected limb's *performance* on activities of daily life, on the Fugl-Meyer ($p = 0.019$) and Motor Activity Log scales, both in the control of quantity of movement (AOU $p < 0.001$) and in the control of quality of movement (QOM $p < 0,001$)[2] **(A)**.

On patients with mild to moderate disability of hand function, in average eighty months post-EVA, the constraint-induced movement therapy, applied for six hours of intensive training a day, not including weekends, for two weeks, and use of unaffected upper limb constraint during 80% to 90% of waking hours maintains the hand's functional improvements for a four year period after the intervention (MAL AOU *score*, $p < 0.01$; MAL QOM *score*, $p < 0.05$)[3] **(B)**.

The constraint-induced movement therapy applied for ten consecutive days, with daily six-hour intensive training and immobilization of the unnafected hand during 90% of the waking hours, is effective for the functional improvement of the paretic upper limb ($p < 0.001$), both regarding *performance*, 37.58%, $p = 0.030$) and skill (10.38%, $p = 0.037$) in short term, but not in the long term, six months, considering an average of twenty-three months from onset[4] **(A)**.

When compared to the bilateral training of upper limb performed for two hours a day, five days a week for three weeks, the constraint-induced movement therapy associated with movement restraint of the affected upper limb for six hours a day and intensive training of the paretic upper limb for the same period of two hours a day, five days a week, during three weeks, is better for the improvement of the "locomotion" item on the Functional Independence Measure ($p = 0.011$), for the improvement of the quality-related *scores* ($p = 0.004$) and quantity ($p = 0.042$) of movement of the *Motor Activity Log*, in the evaluation of the upper limb function of the affected limb after the EVA. The constraint-induced movement therapy is also better than bilateral training for promoting higher quality of life (Stroke Impact Scale - SIS: $p = 0.003$) and in the controls related to the performance of Activities of daily life and Instrumental Activities of daily life (SIS: $p = 0.024$) and social participation (SIS: $p = 0.009$)[5] **(A)**.

Recommendation

The constraint-induced movement therapy, when performend between ten and fifteen, associated with the restraint of the unaffected upper limb for 80% to 90% of the waking hours for two to six hours of intensive repetitive and standardized training, is recommended for the functional recovery of the upper limb affected by chronic EVA, impacting in the improvement of the Activities of daily life and Instrumental Activities of daily life, as well as in these patients' higher quality of life. However, the maintenance time of the improvements acquired varies according to the intervention time, as well as the protocol used.

2. Does the use of FES benefits the treatment of hemiplegic upper limbs of patients with EVA in chronic phase?

The bilateral movement training of the upper limbs associated with the use of functional electrical stimulation FES may be an effective method in the rehabilitation of the upper limbs of patients with EVA, chronic, after fifteen training sessions, each intervention session with 1.5 hour duration, of those, ten minutes for stretching; twenty-minutes of using FES associated with bilateral tasks that demand hand manipulation and sixty minutes of occupational therapy conventional treatment.

FES parameters: 40 Hz stimulation frequency; 200 mms pulse width; 3.8 cm diameter electrodes applied to the superficial motor point on the extensors and thumb long abductor.

The FES group post-treatment showed improvement on the Fugl-Meyer Assessment ($p = 0.039$) *scores*, for the active movement amplitude of wrist extension ($p = 0.020$) and on the *Functional Test for the Hemiplegic Upper Extremity* ($p = 0.001$)[6] **(A)**.

The use of FES in a daily program at home, in the course of a five month period with duration of six days a week, as a continuation of the clinical rehabilitation, may improve, effectively, the wrist movement amplitude in 6.23 ($p < 0.05$) and fingers 6.95 ($p < 0.05$) and for shoulder flexion 22.1 ($p < 0.001$); the motor *performance* regarding time in the tests 10 - cmt: f = 18.72, ($p < 0.01$) and 9 - pht: f = 12.27, ($p = 0.01$); on the *Modified Ashworth Scale* (MAS) at the beginning of treatment in the wrist area obtained 3:1 and 2:4 and after the treatment obtained 2:1 and 1:4.

Target muscles: extensor carpi radialis brevis and longus, extensor indicis proprius and deltoid[7] **(A)**.

Recommendation

The use of FES provides benefits in the treatment of the hemiplegic upper limb of patient with EVA in the chronic phase, regarding gains of amplitude of movement, spasticity reduction and improvement of upper limb motor function.

This study used as target muscles: extensor carpi radialis brevis and longus, extensor indicis proprius and deltoid.

3. What is the effectiveness of using upper limb orthoses on post-EVA hemiplegic patients?

On patients with subacute hemiplegia, up to eight weeks post-EVA, with no active wrist extension, the use of wrist and fingers positioning static orthosis, with the wrist in neutral position (0-10 degrees) (NP) or at extension, 45°, (EXT), for nine to twelve hours of night use during a period of four weeks, prevents the contraction of the wrist in flexion, when compared to the conventional rehabilitation treatment. There is a loss in the amplitude of movement, AOM, of the wrist after six weeks, four weeks of intervention, plus two weeks of continuance, and the orthotization shows little or no effect in the loss of AOM prevention. The average result of the use of NP orthosis was 1.4°, within four weeks and 4.2° within six weeks. As for the orthosis with the wrist in extension, EXT, showed average result of -1.3° for four weeks and 1.8° for six weeks. It is observed that the orthosis with the wrist in neutral provides less reduction to the wrist extensibility after six weeks when compared to the EXT wrist orthosis with result of 13.3° PN orthosis; 14.3° EXT wrist orthosis. No statistically relevant results were found for upper limb function (*Motor Assessment Scale*), spasticity (Tardieu Scale) and disability (*Disabilities of the Arm Shoulder and Hand* - DASH)[8] **(A)**.

On patients with subacute hemiparesis, two weeks to three months post-EVA, and motor impairment in distal upper limb, the static orthosis for functional realignment or the wrist in neutral position and free fingers, use for a minimum of six hours a day, associated with the conventional rehabilitation treatment, two Physical Therapy sessions and one Occupational Therapy session, daily, and Neuropsychology and Phonoaudiology sessions whenever indicated, after thirteen weeks, showed the reduction of hand pain in 7% occurrence of pain when compared to not using, 53% occurrence of pain, showing significant differences regarding the pain prevention aspect. The motor recovery scales, (FUGL-MEYER), spasticity (Modified Ashworth Scale) and Amplitude of Movement, AOM, passive, however, did not show significant differences. Nevertheless, there is a higher loss of wrist mobility (AOM), changing from 7% at the beginning, to 62% after thirteen weeks[9] **(A)**.

Patients with post-EVA hemiplegia after six months from the lesion, chronic, with amplitude of movement limitation of elbow extension and hypertonia of the elbow flexors, that had Occupational Therapy treatment, two hour sessions, once a week for sixteen weeks, associated with the application of type A botulinum toxin to the muscles: biceps, brachialis and brachioradialis, and the use of dynamic orthosis for elbow extension for six to eight consecutive hours during sleep, showed a significant improvement on the amplitude of movement, AOM, when compared to the application of type A botulinum toxin plus Occupational Therapy, in which there was no use or orthosis, being 33.5% average variation of the AOM in the experimental group versus 18.7% average variation of the AOM in the control group. However, there was no significant improvement in the spasticity scale, being 9.3% average improvement on the Modified Ashworth Scale for the experimental group and 8.6% average improvement for the control group[10] **(B)**.

Patients with chronic hemiplegia and spasticity of upper limb, with no functional use of the hand, that do not use static orthosis for the positioning of wrist and fingers in functional position during the first week, but use orthosis from the third to the seventh weeks when compared to patients that use orthosis from the second to the seventh weeks, i.e., five weeks versus six weeks of orthosis use, it is observed the minimum effect, clinically, valid of reduction of 6 N (newtons), or 40% of normal, in the quantity of resistance of flexors of wrist and fingers and 10° improvement to the amplitude of movement, AOM, of wrist extension. The effects were discreet and did not reach the estimated value, clinically, valid for the reduction of short term muscle resistance, however, the average of long term effect size exceeded the lowest effect, clinically, valid, which suggests that performing studies with a larger sample to demonstrate the results obtained with greater clarity would be indicated. It is demonstrated, therefore, that orthotization may maintain the articular conditions and prevent the loss of AOM, however, it seems not to be effective in the reduction of muscle resistance of the flexors of the wrist and fingers or in the reduction of flexor tone, and also that the use of orthesis for longer periods presents better results than the use for a shorter period[11] **(B)**.

Regarding the use of orthosis for the positioning of wrist and fingers of ventral or dorsal shape, it was observed the reduction of hypertonia of the flexors of wrist and fingers, with no significant differences, within a six week period. There are, however, methodological limitations, which indicates the need for more profound studies and with larger samples[12] **(B)**.

Patients with post-EVA hemiplegia, in the subacute and chronic phases, with no functional hand movement and upper limb spasticity that use ventral static orthosis for the positioning of wrist and fingers in functional position for at least 90 minutes a day, for three months, show significant improvement in the amplitude of movement, AOM, passive of the wrist (pre-intervention, t0 = 123 and 3 months after intervention, t3 = 143 degrees), being more evident in the chronic patients (t0 = 115 and t3 = 142 degrees) than in the subacute ones (t0 = 133 and t3 = 140 degrees). The passive AOM of the elbow presents significant improvement only in the subacute group (t0 = 129 and t3 = 135 degrees). There is also significant reduction in the Modified Asworth Scale for the elbow (t0 = 1.7 and t3 = 1.3), in the severity of the wrist pain and in spasm frequency. The relationship between the maximum amplitude of H reflex and the maximum amplitude of the M response (Hmax/Mmax) of the *flexor carpi radialis* muscle also presents significant reduction[13] **(B)**.

Patients with subacute hemiparesis post-EVA which are treated with conventional rehabilitation five times a week, associated with the electromyographic evaluation with median nerve stimulation for the evaluation of the H reflex and M response in the flexor and extensor muscles of the wrist and fingers and elbow, with and without orthosis for the positioning of the wrist in neutral position and abduction of thumb, presented reduction of the flexor hyperactivity with the use of the orthosis, reducing the coactivation of antagonist muscles, in the fingers, wrist, and elbow. The use of orthosis for ten minutes reduced the reflex excitability when compared to the base evaluation. Patients that used orthosis for eight hours a day, for eight weeks, showed reduction of the flexor sinergy and improvement in the amplitude of movement of the extension of the fingers and flexion of the shoulder, as well as significant reduc-

tion of muscle tone of flexors of the elbow and fingers after eight weeks using the orthosis[14] **(B)**.

The conclusion is that there is not enough evidence to affirm or contest the use of upper limb orthoses in adults after Cerebral Vascular Accident. The widely spread use of upper limb orthoses in EVA cases notwithstanding, only eighteen studies, five of those randomized, assessed the effects of orthothization in this population. The poor methodological quality and the heterogeneity of the study designs, methods, orthosis model, use regimen and results; prejudice the association and analysis of the data found. The majority of published papers was based in opinions with no clear quantitative and statistic analysis, 44%, and, only, 26% of the analyzed studies were based on experimental study designs[15] **(B)**.

Recommendation

It is observed that the use of orthosis shows positive results related to the prevention of reduction of amplitude of movement of the wrist, preservation of the arc of movement, prevention of hand pain and reduction of the spasticity of the flexors of the elbow, wrist and fingers; however, there are no evidences regarding the improvement of upper limb motor function.

The fact should be considered that several aspects influence the indication, type of orthosis, time of use, and short and long term results, among those: post-EVA neurological recovery stage, motor function level, changes in tone, active and passive amplitude of movement, articullary conditions, sensitivity, pain, patient's adherence to the treatment regimens and goals to be achieved with the use of orthosis.

That is why the indication of orthoses should be made by licensed professionals and, preferably, within the rehabilitation treatment context, which allows that the medical staff and occupational therapists perform the specific evaluation and identify the goals to be achieved, thus selecting the adequate orthosis model and its use regimen, and also the evaluation and reevaluation instruments that will ensure that this therapeutic resource is, in fact, effective.

In the clinical practice it is observed the effectiveness of the use of upper limb orthoses with different goals such as: articular alignment, stabilization, and postitioning, maintenance or improvement of the arc of movement, prevention of deformities and contractions, improvement of hand function. However, new studies will be required so that a standardization can exist in the use of this resource in clinical practice based on scientific evidence that will make possible the more precise definition regarding orthosis models to be used and their details, treatment regimens, standard evaluation instruments, and treatment protocols, thus allowing presenting and discussing the benefits of using orthoses in EVA in a clearer and more objective manner, by means of the employment of high quality methodology resources.

4. Does surface electromyographic biofeedback in hemiplegic upper limb brings benefits for post-EVA patients in chronic phase?

Biofeedback, BFB, is the process of physiological events monitoring in humans, with the use of electronic equipment, with display of information in visual and/or audio signals and allows the individual to self regulate a physiological function, i.e., exert a voluntary control over specific physiological responses.

The surface electromyographic *Biofeedback*, EMG-BFB, allows the monitoring of muscle activity by means of surface electrodes placed on the skin that sense myoelectric signals from the muscles and convert them to visual and audio signals, that may be understood and controlled by the patients, in real time, according to specific rehabilitation techniques regarding motor control and neuromuscular reeducation, for the improvement of motor function.

It is a therapeutic resource that has been used on the treatment of hemiplegic patients since the 1960's and since then several studies have been conducted to evaluate its effectiveness within this population, relating benefits in chronic and acute phases, being used on upper or lower limbs, contributing in the global functional recovery.

In the wrist flexor muscles spasticity, upper limb function and skills for the performance of activities of daily life in patients with post-EVA hemiplegia in the subacute and chronic stages, which had conventional rehabilitation and neurodevelopmental treatments, and verbal encouragement to relax spastic flexor or the wrist muscles, the electromyographic *Biofeedback*, EMG-BFB, performed for three weeks of treatment, five times a week during twenty minutes, in which the patient was instructed to maintain muscular activity of the flexors of the wrist in a base line, aiming the muscle relaxation, there was significant improvement in the upper limb function and skills in the performance of activities of daily life (*upper extremity function test*-UEFT $p < 0.05$ / pre-treatment = 0.40 ± 0.82 / post-treatment = 1.20 ± 1.39; Fugl-Meyer Scale - FMS $p < 0.001$ / pre-treatment = 2.40 ± 3.06/ post-treatment = 6.90 ± 6.34; Barthel Index - BI $p < 0.001$ / pre-treatment = 44.50 ± 11.45 / post-treatment = 75.50 ± 14.03), active wrist extension amplitude (Goniometry $p < 0,05$ / pre-treatment = 0.50 ± 2.23 / post-treatment = 13.25 ± 20.92), muscular activity measurements ($p < 0.001$ / pre-treatment = 288.68 ± 68.09 / post-treatment = 233.42 ± 15.04) and spasticity reduction (Ashworth Scale $p < 0,05$), being Ashw 1 pre-treatment = 1 (5%) / post-treatment = 12 (60%), Ashw 2 pre-treatment = 12 (60%) / post-treatment = 8 (40%), and Ashw 3 pre-treatment = 7 (35%) / post-treatment = 0 (0). When compared to conventional treatment, there is significant difference in the upper limb function items, ULF, skills in the performance of activities of daily life, BI, and for the spasticity reduction, Ashworth, in favour of the EMG-BFB treatment[16] **(A)**.

In patients with subacute hemiparesis, in therapeutic exercises program based on Brunnstom's neurophysiological approach, forty five minutes a day, during twenty sessions, associated with the electromyographic *Biofeedback*, EMG-BFB, in which the instruction was to perform wrist extension according to visual and audio feedback observed through the session, administered five times a week, during twenty minutes, for twenty sessions, were observed significant improvements on the motor function recovery scales (Brunnstrom Scale ($p < 0.01$), however, with no significant differences between EMG-BFB and placebo. Nevertheless, the results for amplitude of movement of the wrist ($p < 0.001$; $p < 0.05$) and surface electromyographic potentials ($p < 0.001$; $p < 0.01$) show significant differences in favour of EMG-BFB[17] **(A)**.

In patients with chronic hemiplegia, with upper limb functional limitation and hypertonia of the flexors of the elbow, the intervention with standardized movements of extension of the elbow associated with *biofeedback*, EMG-BFB, in twenty-five-minute sessions, for ten sessions, showed significant improvement in the amplitude of movement of the elbow (control group = 14.90 $p = 0.021$ / experimental group = 16.95 $p = 0.008$), however, when compared to the placebo no difference was observed. There was improvement in the activation of the upper limb muscles during the tasks asked, with significant improvement in the electromyographic activity of the triceps

which performed EMG-B (control group = 6.92 $p = 0.15$ / experimental group = 14.21 $p = 0.035$)[18] **(A)**.

Patients with chronic hemiplegia and hand function limitation that received Occupational Therapy and application of Functional Electrical Stimulation treatment (OT + FES) twice a week, compared to the *Biofeedback*, EMG-BFB treatment, in addition to OT + FES, during a period of twelve months, are observed significant results at six and twelve months for the improvement of amplitude of movement, AOM, of wrist on both groups (OT + FES group: initial 30.71 ± 53.33 / after six months 38.21 ± 60.80 / after twelve months 39.29 ± 62.29 and EMG-BFB group: initial 33.87 ± 51.10 / after six months 75.81 ± 53.28 / after twelve months 101.93 ± 51.54 with $p < 0.001$); and improvement of AOM of the elbow (OT + FES group: baseline 48.21 ± 60.43 / after 06 months 66.43 ± 61.78 / after twelve months 74.28 ± 63.97 and EMG-BFB group: initial 79.03 ± 53.43 / after six months 125.81 ± 29.86 / after twelve months 140.64 ± 27.32 with $p < 0.001$). It was also observed significant improvement of hand function (OT + FES group: initial 20.18 ± 35.92 / after six months 24.15 ± 37.02 / after twelve months 25.15 ± 37.46 and EMG-BFB group: initial 27.06 ± 33.81 / after six months 47.80 ± 33.63 / after twelve months 57.56 ± 35.58 with $p < 0.001$) and hand dexterity (OT + FES group: initial 0.0073 ± 0.1608 / after six months 0.0092 ± 0.1929 and EMG-BFB group: initial 0.0082 ± 0.1581 / after six months 0.209 ± 0.2119 / after twelve months 0.2461 ± 0.2346 with $p < 0.001$). There was also reduction of spasticity on both groups for the flexors of the elbow (OT + FES group: initial 1.37 ± 0.85 / after six months 0.98 ± 0.77 / after twelve months 0.84 ± 0.63 and EMG-BFB group: initial 1.74 ± 0.78 / after six months 1.08 ± 0.61 / after twelve months 0.74 ± 0.50 with $p < 0,001$) and flexors of the wrist (OT + FES group: initial 1.34 ± 0.92 / after six months 1.00 ± 0.72 / after twelve months 0.86 ± 0.62 and EMG-BFB group initial 1.66 ± 0.77 / after six months 1.08 ± 0.62 / after twelve months 0.72 ± 0.48 with $p < 0.001$). The comparison between both groups did not show significant differences in items regarding manual dexterity ($p = 0.067$), AOM of the elbow ($p = 0.07$), spasticity of the elbow ($p = 0.47$) and spasticity of the wrist ($p = 0.59$), but it demonstrated significant diffrerences in the items of AOM of the wrist ($p = 0.02$) and hand function ($p = 0.02$), in favour of the *Biofeedback* treatment. The evaluation tools used were the Modified Ashworth Scale, the *Minnesota Manual Dexterity Test,* and the *Hand Function Test* [19] **(A)**.

The use of surface electromyographic *Biofeedback* intended for motor function recovery, in patients with post-EVA hemiplegia, does not show effects for the improvement in the amplitude of movement and functional skill, but there are evidences of improvement in the amplitude of movement of upper limb articulations, motor function, functional recovery and gait quality when associated with the conventional rehabilitation treatment, such as physical therapy. It was not possible to conclude if the observed benefits can be maintained or tend to be reduced with time. It was also concluded that EMG-BFB can be considered a safe treatment since there were no reports of adverse effects In the analyzed studies, and that randomized controlled studies are necessary, with adequate evidence strength and padronized evaluation tools for ascertaining the effectiveness of the *Biofeedback* treatment[20] **(A)**.

Recommendation

The use of *Biofeedback*, EMG-BFB, in the rehabilitation of patients with post-EVA hemiplegia, focused on the upper limbs, shows evidences of benefits in the improvement of articular amplitude of movement, muscular activity, reduction of spasticity, improvement of motor function, and in the performance of the activities of daily life.

Because of this, EMG-BFB is not a routine treatment for hemiplegic patients, but a complementary therapeutic resource to the conventional rehabilitation treatment, which can perfect the results and shows benefits on a shorter treatment period while it provides an improvement in the patient's body perception and movement consciousness, showing better motor responses in a shorter period of time when compared to therapeutic situations in which this kind of *feedback* is not provided.

The evaluation tools for amplitude of movement, spasticity, motor function, functional performance, hand function and propioception must be applied in a padronized manner in order to evaluate the benefits of this type of treatment for each case and must be associated with the analysis of muscular activity shown by the equipment, which must be performed continuously.

For a better definition regarding the effectiveness of the use of *Biofeedback* and to demonstrate in a more padronized manner and with adequate methodological quality, the benefits observed in clinical practice, which will allow EMG-BFB to be known as an important therapeutic resource in the treatment of patients with post-EVA hemiplegia, and that more people have access to this type of treatment, that can contribute in a positive manner to the rehabilitation.

5. What are the benefits of bilateral training compared to unilateral training in the treatment of patients in post-EVA chronic phase?

Regarding unilateral training, the upper limbs bilateral training, both combined to the neuromuscular stimulation, applied in ninety-minute sessions, four days a week, for two weeks, is better for the improvement of the movement time ($p < 0.01$), speed ($p < 0.038$) and speed variation ($p < 0.029$), as well as in the movement deceleration time ($p < 0.026$) in the paretic upper limb[21] **(B)**.

Bilateral training also provides positive impacts in movement generalization, i.e., in the distal to proximal transference of the upper limb with EVA in the chronic phase[21] **(B)**.

Patients with EVA in the chronic phase, average 6.3 years after the episode, present significant improvement in the motor skills of the paretic upper limb after six days of bilateral training (*Modified Motor Assessment Scale* - MAS *score*: $p = 0.0234$), as well as reduction of the excitability of the motor cortex of the unaffected hemisphere (TMS: $p = 0.09$). When compared to the unilateral training, the bilateral training is better for the recovery of the paretic upper limb function (MAS *score*: $p = 0.0094$) and there is no difference in the excitability of the motor cortex of the unaffected hemisfhere ($p > 0,7$)[22] **(A)**.

However, there are no evidences of improvement by means of kinetic variables after the intervention when compared to unilateral training[22] **(A)**.

Compared to unilateral training, bilateral training provides improvement in the movement speed of the paretic upper limb ($p < 0.01$), as well as in the precision and smoothness in reaching tasks ($p < 0.001$). There is correlation between the improvement in the speed and in the *performance* of the time component of the *Wolf Motor Arm Test* ($p < 0.045$)[23] **(A)**.

Bilateral training, performed during six weeks, three times a week, in one-hour sessions, improves the bimanual skills (Wolf Time: $p < 0.03$; Wolf Weight: $p < 0.015$) whereas the unilateral training

improves the *performance* only in the unilateral reaching tasks (*Wolf Time*: $p < 0.10$; Wolf Weight $p < 0.05$)[23] **(A)**.

Bilateral training performed on patients suffering from EVA, chronic, with moderate disability of the paretic upper limb (*Fugl-Meyer Upper Extremity score*: 19 - 40) is better in comparison with unilateral training, performed during eight weeks, three times a week, with one-hour sessions, in the improvement of the shoulder stability and movement (*Motor Assessment Scale/Upper Arm Function*: $p > 0.021$)[24] **(A)**.

There is also significant improvement from bilateral training, not compared to unilateral training, of 27% in shoulder stability and movement function and 18% in upper limb global function, i.e., on all items of the *Motor Assessment Scale*, including gross and fine motor functions ($p = 0.02$)[24] **(A).**

Bilateral training provides the enhancing of muscular strength for flexion of the shoulder ($p = 0.002$), flexion of the wrist ($p = 0.029$) and extension of the fingers ($p = 0.05$)[24] **(A)**.

Recommendation

Training with bilateral functional activities for the upper limbs of patients with EVA in chronic phase, with mild to moderate disability, performed for two to eight weeks is superior compared to unilateral training in the functional improvement of the paretic upper limb, but with greater evidence for proximal gains, shoulder and elbow movement, when evaluated by the *Motor Assessment Scale*, MAS. There is also superiority of the bilateral training in the components: kinematic, speed, deceleration and smoothness of movement during performance of reaching tasks with upper limbs.

On the other hand, the application of bilateral training in an isolated manner improves muscular strength for the movements of flexion of the shoulder, flexion of the wrist and extension of the fingers, corresponding to the improvement of the global function in bimanual skills.

6. Is the robot-assisted therapy effective for the improvement of hemiplegic upper limb motor control in the post-EVA chronic phase?

Robot-assisted therapy, performed three times a week for six weeks in one-hour sessions, applied to post-EVA patients in the chronic phase, average of thirty-one months after the episode, reduces, significantly, disability, from moderate to severe, of the paretic upper limb (Fugl-Meyer: $p = 0.001$), with higher evidence for gains in shoulder and elbow (Motor Status Scale *score*: $p = 0.01$), as well as provides enhancement of muscular strength also in shoulder and elbow muscles (Medical Research Council: $p < 0.0001$). For hand and wrist movements, there is moderate improvement ($p = 0.03$), however nonspecific. There is no evidence of improvement in shoulder pain after intervention ($p = 0.07$), as well of improvement of spasticity ($p = 0.23$)[25,26] **(A)**.

Compared to sensorimotor robotic therapy, i.e., with robot-assisted movements, the progressive resistance therapy, opposed force generated by the robot, provides improvement, more significant, in the wrist and hand movements (MSS: $p = 0.006$), considering that the progressive resistance therapy was performed for a three week period[25,26] **(A)**.

In the period of four months after intervention, there are significant evidences of maintenance of the gains regarding voluntary movement (Fugl-Meyer: $p < 0.0001$) and muscular strength (Medical Research Council: $p < 0.0001$) in upper limb, with greater significance for shoulder and elbow movements (Motor Status Scale *score*: $p < 0.0001$)[25,26] **(A)**.

When both robotic techniques are compared, resistance training and active assistive training with one-hour sessions, three times a week, for six weeks, adding up to eighteen hours of intervention, there are no differences regarding gain of voluntary movement, on the improvement of strength and muscle tone. There are greater evidences of improvement to the voluntary movement of the paretic upper limb in patients with mild disability than in those with severe disability[27] **(A)**.

Patients with time over twelve months after EVA, with moderate to severe upper limb disability, receiving training in functional components of tasks without technological assistance, for 3.5 hours a day, five days a week, for twelve weeks, show significant improvement to the upper limb function after the intervention with robotic therapy, emphasizing shoulder and elbow, when compared to the functional neuromuscular stimulation, FNS, applied to the muscles of the wrist and fingers, both for 1.5 hour a day, (*Arm Motor Ability Test*: $p = 0.026$) with greater evidence for the tasks that include components of movements for shoulder and elbow (AMAT-S/E: $p = 0.023$). In contrast, FNS improves the performance of the paretic upper limb in tasks that include distal movements components, wrist and hand, (AMAT-W/H: $p = 0.049$)[28] **(A)**.

Both FNS and robotic therapy, provide significant improvement in the voluntary and synergetic movement of the paretic upper limb (Fugl-Meyer UE: $p = 0.028$ and $p = 0.026$, respectively)[28] **(A)**.

Regarding the improvement of movement precision and smoothness, robotic therapy ($p = 0.042$, $p = 0.013$, respectively) is more effective when compared to FNS ($p = 0.69$, $p = 0.190$, respectively)[28] **(A)**.

In the period of six months after intervention, there are no evidences of maintenance of the gains both for FNS and robotic therapy[28] **(A)**.

Compared to intensive therapy, the Interactive Motion robot-assisted therapy applied on patients with time over six months after EVA, with moderate to severe disability, administered in eighteen one-hour sessions, three times a week, for six weeks or thirty-six one-hour sessions, three times a week, over a twelve week period, does not provide evidence of improvement to the voluntary movement, as well as in the functionality of the paretic upper limb according to the Fugl-Meyer Upper Limb scale, *Motor Power Scale for Shoulder/Elbow,* and *Wolf Motor Function scales*[29,30] **(A)**.

There are no evidences of lower cost of robotic therapy when compared to intensive treatment[29,30] **(A)**.

For patients also with time over six months after the EVA episode, for all levels of disability, mild, moderate, and severe, the robotic therapy with the *mirror image movement enabler*, MIME, distributed over twenty-four fifty-minute sessions, for two months, when compared to conventional therapy of equal intensity and duration, is superior regarding the improvement of proximal voluntary movement (Fugl-Meyer: $p < 0.03$), both on the first month (Fugl-Meyer: $p < 0.05$) and on the second month (Fugl-Meyer: $p < 0.05$), as well as of the proximal muscular strength ($p < 0.02$) after two months from the intervention. Regarding reach, the robotic therapy is superior to the conventional therapy ($p < 0.01$) after two months of treatment[31] **(A)**.

There is no difference between robotic and conventional therapies regarding the improvement of the voluntary movement of the paretic upper limb after six months from the intervention, as well as

regarding the improvement in the functionality, Barthel Index, and Functional Independence Measure[31] **(A)**.

The robotic therapy performed over a two-month period in twenty-four fifty-minute sessions, provides expressive improvement both in the proximal voluntary movement (Fugl-Meyer: $p < 0.001$) and in the distal movement (Fugl-Meyer: $p < 0.001$). There are evidences of improvement (FIM: $p < 0.04$) of functionality after six months from the intervention with robotic therapy. Regarding muscular strength, the robotic therapy provides significant gains in the extension of the elbow, abduction, adduction flexion of the shoulder ($p < 0.05$)[31] **(A)**.

With the robotic technology equipment coupled to virtual reality, after twenty-four sessions, patients with EVA moderate to severe disability, there is no difference when compared to conventional semi-autonomous exercises, partial therapist supervision, related to the functionality of the paretic upper limb, however, there is expressive improvement to the prehension strength ($p = 0.01$). Both robotic and conventional therapies provide modest improvement in the upper limb function. After six months of intervention, the robotic therapy shows superiority compared to conventional therapy regarding the gain in voluntary movement (Fugl-Meyer: $p = 0.045$). The robotic therapy produces results with greater evidence for gains in proximal upper limb[32] **(A)**.

Ninety percent of patients prefer the robotic technology equipment coupled with virtual reality to the conventional therapy[32] **(A)**.

Recommendation

There are two specific techniques proceeding from the robotic technology systems: robot active-assisted training or training resisted by the robot. Both techniques, applied three times a week, over a variable period of six to twelve weeks, provide modest results, however, expressive of improvement in the functionality of the paretic upper limb, more, specifically, proximal, in patients with EVA in chronic phase, with mild, moderate and severe disability. There are few evidences that such gains are maintained after six months of intervention.

However, when such techniques are compared to the conventional intensive therapy, padronized and repetitive there is no difference regarding results. Compared to neuromuscular functional stimulation, the robotic therapy is superior regarding the improvement in the precision and smoothness of movements.

On the other hand, the system applied for twenty-four fifty-minute sessions, during two months, four weeks, improves, significantly, the function of the paretic upper limb and functionality during activities of daily life after the intervention, however, there is no evidence of maintenance of such gains after six months.

There is not enough evidence regarding the effectiveness of robotic therapy on the improvement of motor control in the paretic upper limb of patients with EVA in chronic phase.

7. Is gait training on the treadmill, with or without body-weight support, more effective than overground gait training for hemiplegic patients?

Gait training of hemiplegic patients on the treadmill shows significant improvement compared to patients who perform overground gait training. The improvement is related to distance ($p < 0.04$), speed ($p < 0.003$), step length of R leg ($p < 0.009$) and L leg ($p < 0.003$) and step width, bilaterally, ($p < 0.01$), indicating a more symmetric use of the lower limbs[33] **(A)**. Patients who perform body-weight-supported treadmill training, either associated with the electrical stimulation of the lower limb or not and patients who perform overground gait training show improvement in gait; ten-meter test ($p < 0.001$), six-minute test ($p < 0.001$), MMAS scale test, *Modified Motor Assessment Scale,* ($p < 0.001$), dynamic balance test ($p < 0.001$). However, there are no differences between the groups. One possibility for this similarity is the fact that the randomized patients for the overground training were trained on speeds higher than 2 k/h of the treadmill protocol and also without cane, with average age of fifty-two years[34] **(A)**. Patients who perform body-weight-supported treadmill gait training show improvement in the gait pattern, verified by means of the functional balance ($p = 0.001$), motor recovery ($p = 0.001$), gait speed ($p = 0.029$), gait resistance ($p = 0.018$), when compared to those patients who perform gait training on the treadmill without body-weight suspension[35] **(A)**.

Recommendation

Gait training for hemiplegic patients on the treadmill with or without body-weight support is effective. However, the overground gait training also provides functional gains to the hemiplegic patient.

8. Which is the most effective postural balance training for patients with chronic EVA?

In the balance training of the patient with EVA, chronic, some aspects must be considered, such as: the balance strategies adopted by the patients, postural reflexes, static balance, weight distribution on lower limbs, LLLL, and the patient's risk of falling. The Berg Balance scale, the Timed Up and Go test, TUG, the time of the step balance strategy and the body-weight distribution over the LLLL measured on the force platform are good measurement tools for the assessment of the fall risk and mobility of the patients and may be applied before and after training. Conventional physical therapy techniques, such as LLLL stretchings, mostly, of the spastic muscle groups of patients with EVA, muscular strengthening on higher postures such as in orthostatism[36] **(A)**, training on postural change from sitting to orthostatism, gait and balance training[37] **(A)**. Other techniques intended for dynamic balance, for instance, the training of patient's agility by means of different types of gait; figure of eight walking, different step lengths and speeds, side stepping, crossover stepping, and stepping over obstacles[36] **(A)**. On training, sit-to-stand movements, may be performed either on hard or foam ground, the knee flexion angle can be changed from 105° to 90° and later to 75°, making the task harder and demanding more strength from the knee extensor muscles[37] **(A)**. A distinct technique was used that can be combined with all the others is the omission of visual information: keeping the patients' eyes closed[36,37] **(A)**.

Recommendation

The most effective balance training is that which associates conventional physical therapy with agility techniques and offers the greatest number of sensory experiences.

9. Is gait training with orthosis more effective for the improvement of the hemiparetic patient's gait pattern than training without orthosis?

In general, patients that perform gait test with orthoses show better results when compared to the same test without orthosis[38-41] **(A)**. There is a difference in gait performance when the assessment is made with patients used to the orthosis in daily life. These are capable of performing the tests with superior improvement in the gait

pattern when compared to the ones that used the orthosis for the first time[38] **(A)**. The energetic spent is usually lower on patients that walk with an orthosis. Besides, step length and balance phase grow, thus reducing, considerably, the double support phase[41] **(A)**.

The use of orthosis can be associated with the use of electrical stimulation for dorsiflexor musculature activation in the chronic hemiparetic patient. In this case, the use of isolated orthosis and of isolated electrical stimulation when compared to not using any of the resources show better results. When both resources are compared, there are no significant differences and in general better results tend to be achieved solely with the use of ankle-foot orthosis[39] **(A)**.

The patient's opinion regarding the procedure is very important and must be taken into consideration. Improvement in self confidence and assurance in walking are reported when the resource is used to stabilize the ankle during the walk[38,39] **(A)**. In addition to this, improvement in motor control should be observed to select the most adopted resource to be indicated for each individual[40] **(A)**.

Recommendation

When discussing the improvement in gait pattern, gait training with orthosis shows better results compared to gait training without orthosis. The most used orthosis is the ankle-foot orthosis, AFO, which is capable of better stabilizing the ankle joint, providing better propioception to the hemiparetic limb and consequently improving posture and gait pattern.

10. Is sensory stimulation with the use of TENS effective in the improvement of balance or gait patterns in patients with EVA sequelae?

The electrical stimulation with the use of TENS is largely used in rehabilitation for analgesia purposes, however, there are parameters that can be set in the TENS equipment that produce effects only in sensory level. Such sensory effects could be considered as another sensory stimulation instrument on patients with EVA sequelae. Sensory modification of these patients is partially responsible for the change in balance and gait disorders[42,43] **(A)**.

The use of transcutaneous electrical nerve stimulation, TENS, in patients with EVA sequelae in the chronic phase, for sixty minutes five times a week for at least four weeks with 100 Hz frequency and 0.2 ms pulse width settings[42,43] is effective in improving peak torque of dorsiflexors and plantiflexors[43], in addition to being effective in improving gait speed up to three times over[42] when compared to not using[42,43] **(A)**.

There were no consistent evidences to support the use of TENS to improve balance in patients with EVA sequelae in the chronic phase.

Recommendation

Regarding transcutaneous electrical nerve stimulation with sensory parameters for improved function of lower limbs and gait pattern, the use for sixty minutes, five times a week for at least four weeks with 100 Hz frequency and 0.2 ms pulse width settings is effective.

11. Does the use of functional electrical stimulation reduce spasticity in post-EVA chronic patients?

With the use of electrical stimulation in the ankle dorsiflexor muscles, stimulation current parameter settings: frequency 50 Hz and pulse 0.4 ms, patients present significant spasticity reduction by the Modified Ashworth Scale - MAS (p = 0,000)[44] **(A)**. When the patients are treated with the Bobath technique and in half the group is applied electrical stimulation to the dorsiflexor muscles, stimulation current parameter settings: frequency 100 Hz and pulse 0.1 ms, the results of this combination therapy indicates a significant spasticity reduction according to MAS (p = 0,0001)[45] **(A)**. By using another methodology, the electrical stimulation in the muscle-tendon junction of the gastrocnemius muscle, stimulation current parameter settings: frequency 20 Hz and pulse 0.2 ms, there is a significant improvement in the spasticity measured by the Modified Ashworth Scale, MAS[46] **(B)**.

Recommendation

The use of electrical stimulation reduces lower limb spasticity in hemiplegic patients when used according to the principle of reciprocal innervation, ankle dorsiflexor muscles, or to the principle of increasing activation of type IIb muscle fibers, muscle-tendon junction of the gastrocnemius muscle.

12. Does the use of virtual reality as therapeutic intervention provide benefits to patient with chronic EVA sequelae?

Virtual reality refers to a wide range of technologies that provide sensory visual and propioceptive information, artificially generated by real world objects and events simulators[53] **(B)**.

Several responses are expected with the use of this technology. From balance improvement[47] **(B)**, upper limb function[50,56] **(B)**[55] **(C)**[57] and gait[49] **(B)**[54], **(A)** to cognitive and autonomy improvements[51,52] **(B)**.

Static Balance: There are no confirming evidences to the effectiveness of the use of virtual reality as a therapeutic instrument for patients with chronic EVA sequelae, using the virtual reality program in thirty-minute sessions, four times a week[47] **(B)**.

Dynamic Balance: There is improvement of patients with chronic EVA sequelae with the use of virtual reality as a therapeutic instrument, using the virtual reality program in thirty-minute sessions, four times a week[47] **(B)**.

Gait Improvement: The use of virtual reality in combination with treadmill gait training, provides up to twelve times improvement in the gait of patient with chronic EVA sequelae, when the equipment Rutgers Ankle Rehabilitation System, RARS, is used three times a week, for four weeks, in sixty-minute interventions or with the virtual reality system Fastrack Polhemus, in twenty-minute sessions, three times a week for at least three weeks[49] **(B)**[54] **(A)**. There is also improvement in the lower limb control in the toe-off phases in the gait pre-balancing phase, when using the IREX VR program in sixty-minute sessions, five times a week for, at least, four weeks[48,49] **(B)**.

Amplitude of Movement Improvement: There are no evidences to prove that the use of virtual reality could improve lower limb amplitude of movement, when using lower limb virtual reality equipment, three times a week, for four weeks and approximately sixty-minute interventions[49] **(B)**. However, regarding upper limbs, the use of virtual reality improves amplitude of movement of the thumb in 80% and 20% of the other fingers, when using the Rutgers Master II-ND equipment and the Cyber Glove, for at least thirteen trainings, five times a week for three weeks[57] **(B)**.

Upper limb function improvement: The use training with virtual reality programs for functional recovery of upper limbs is cabable of reducing up to four times the time of performance tasks that require fine motor skills, when using either the Rutger Master II-ND equipment, or virtual reality semi-immersion workstation, or the Virtual

Mall, Vmall program, or using the Nintendo Wii Tods videogame in sixty-minute sessions, four to five times a week, for at least four to five weeks[40] **(A)**[55,57] **(C)**[56] **(B)**. There is functional improvement with difference power of 95,68%[55] **(C)**. The same protocol on the Rutgers Master II-ND equipment also provides up to 188% improvement in the fractionation of the use of fingers of patient with chronic EVA sequelae[57] **(B)**.

Behavioral improvement: There is no difference regarding behavioral, cognitive or autonomy aspects with the use of virtual reality programs for patients with chronic EVA sequelae, when using non-immersive virtual reality system or with the 2DVR program, in forty-five-minute sessions, three times a week for at least thirty-four weeks[51,52] **(B)**.

Recommendation

The use of virtual reality in sixty-minute sessions, four to five times a week for four to five weeks, is capable of improving dynamic balance, gait pattern, lower and upper limbs amplitude of movement and upper limb function, in patients with chronic EVA sequelae.

13. Is muscular strengthening effective for the functional improvement of patient with chronic EVA?

The muscular strength training must be performed with a combination of exercises, three times a week and for at least three months. The training organization must start with a fifteen to twenty-minute warm-up to increase circulation and mobility and then start the muscular resistance exercises with an exercise circuit that includes: ergometric bicycle, weight training with approximately 1.5 kg, therapeutic ball exercises, walking with ankle weights, upper limbs exercises performed in a standing position with elastic resistance, going up and down stairs. The training time in this circuit must be progressively increased from fifteen to forty minutes. To end the training, global stretching exercises performed in a standing position. The functional gains with this type of training can be evaluated with questionnaires such as the SF-36 survey which in its physical portion assesses activities of daily life, with the Time Up and Go (TUG) and with gait energetic spent tests[58] **(A)**.

Recommendation

The strength training is effective in the functional improvement of patients with chronic EVA when performed in circuit format with aerobic training and daily life simulation activities.

14. Does surface electromyographic *biofeedback* improve gait pattern of patient with chronic EVA?

When comparing chronic post-EVA patients that receive conventional physical therapy with those that receive physical therapy with electromyography with visual and audio *biofeedback*, it is observed that the latter ones show improvement in the muscular recruiting of the tibialis anterior muscle for dorsiflexion during gait, after intervention[59] **(A)**[60] **(B)**. In the gait analysis at the gait laboratory, step length and gait speed do not change[59] **(A)**. The improvement in gait pattern occurs due to the increased dorsiflexion strength and the ability to overcome foot drop during the balance phase of gait[60] **(B)**.

Recomendation

Electromyographic biofeedback increases muscular strength and improves functional locomotion in patients with hemiparesia and foot drop.

REFERENCES

1. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, Morris D et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the excite randomized clinical trial. JAMA 2006;296:2095-2104.
2. Wu CY, Chen CL, Tang SF, Lin KC, Huang YY Ching-yi Wu, Chia-ling Chen, et al. Kinematic and clinical analyses of upper-extremity movements after constraint-induced movement therapy in patients with stroke: a randomized controlled trial. Arch Phys Med Rehabil. 2007;88(8):964-70.
3. Brogardh C, Flansbjer UB. What is the long-term benefit of constraint-induced movement therapy? a four-year follow-up. Clin Rehabil. 2009;23:418-423.
4. Dahl AE, Askim T, Stock R, Langorgen E, Lydersen E, Indredavik B. Short and long-term outcome of constraint-induced movement therapy after stroke: a randomized controlled feasibility trial. Clin Rehabil. 2008;22:436-447.
5. Lin K, Chang Y, Wu C, Chen Y. Effects of constraint-induced therapy versus bilateral arm training on motor performance, daily functions, and quality of life in stroke survivors. Neurorehabil Neural Repair. 2009;23(5):441-8.
6. Tong RK, Chung KY. Bilateral upper limb training with functional electric stimulation in patients with chronic stroke. Neurorehabil Neural Repair. 2009;23(4):357-65.
7. Hara Y, Ogawa S, Tsujiuchi K, Muraoka Y. A Home-based rehabilitation program for the hemiplegic upper extremity by power-assisted functional electric stimulation. Disabil Rehabil. 2008;30(4):296-304.
8. Lannin NA, Cusick A, McCluskey A, Herbert RD. Effects of splinting on wrist contracture after stroke: a randomized controlled trial. Stroke 2007;38(1):111-6.
9. Bürge E, Kupper D, Finckh A, Ryerson S, Schnider A, Leemann B. Neutral functional realignment orthosis prevents hand pain in patients with subacute stroke: a randomized trial. Arch Phys Med Rehabil. 2008;89(10):1857-62.
10. Lai JM, Francisco GE, Willis FB. Dynamic splinting after treatment with botulinum toxin type-A: a randomized controlled pilot study. Adv Ther. 2009;26(2):241-8.
11. Sheehan JL, Winzeler-Merçay U, Mudie MH. A randomized controlled pilot study to obtain the best estimate of the size of the effect of a thermoplastic resting splint on spasticity in the stroke-affected wrist and fingers. Clin Rehabil. 2006;20(12):1032-7.
12. McPherson JJ, Kreimeyer D, Aalderks M, Gallagher T. A comparison of dorsal and volar resting hand splints in the reduction ofhypertonus. Am J Occup Ther. 1982;36(10):664-70.
13. Pizzi A, Carlucci G, Falsini C, Verdesca S, Grippo A. Application of a volar static splint in poststroke spasticity of the upper limb. Arch Phys Med Rehabil. 2005;86(9):1855-9.
14. Fujiwara T, Liu M, Hase K, Tanaka N, Hara Y. Electrophysiological and clinical assessment of a simple wrist-hand splint for patients with chronic spastic hemiparesis secondary to stroke. Electromyogr Clin Neurophysiol. 2004;44(7):423-9.
15. Lannin NA, Herbert RD. Is hand splinting effective for adults following stroke? A systematic review and methodologic critique of published research. Clin Rehabil. 2003;17(8):807-16.
16. Doğan-Aslan M, Nakipoğlu-Yüzer GF, Doğan A, Karabay I, Özgirgin N. The effect of electromyographic biofeedback treatment in improving upper extremity functioning of patients with hemiplegic stroke. J Stroke Cerebrovasc Dis. Epub 2010 Sep 29.
17. Armagan O, Tascioglu F, Oner C. Electromyographic biofeedback in the treatment of the hemiplegic hand: a placebo-controlled study. Am J Phys Med Rehabil. 2003;82:856-61.
18. Wolf SL, Catlin PA, Blanton S, Edelman J, Lehrer N, Schroeder D. Overcoming limitations in elbow movement in the presence of antagonist hyperactivity. Phys Ther. 1994;74(9):826-35.
19. Lourenção MI, Battistella LR, de Brito CM, Tsukimoto GR, Miyazaki MH. Effect of biofeedback accompanying occupational therapy and functional electrical stimulation in hemiplegic patients. Int J Rehabil Res. 2008;31(1):33-41.
20. Woodford H, Price C. EMG biofeedback for the recovery of motor function after stroke. Cochrane Database Syst Rev. 2007;(2):CD004585.
21. Cauraugh JH, Kim SB, Duley A. Coupled bilateral movements and active neuromuscular stimulation: Intralimb transfer evidence during bimanual aiming. Neurosci Lett. 2005;382:39-44.
22. Summers JJ, Kagerer FA, Garry MI, Hiraga CY, Loftus JA, Cauraugh JH. Bilateral and unilateral movement training on upper limb function in chronic stroke patients: a TMS study. J Neurological Sci. 2007;252:76-82.
23. Waller SM, Liu W, Whitall J. Temporal and spatial control following bilateral versus unilateral training. Hum Mov Sci. 2008;27(5)749-758.
24. Stoykov ME, Lewis GN, Corcos DM. Comparison of bilateral and unilateral training for upper extremity hemiparesis in stroke. Neurorehabil Neural Repair. 2009;23:945.

25. Fasoli SE, Krebs HI, Stein J, Frontera WR, Hogan N. Effects of robotic therapy on motor impairment and recovery in chronic stroke. Arch Phys Med Rehabil. 2003;84:477-82.
26. Fasoli SE, Krebs HI, Stein J, Frontera WR, Hughes R, Hogan N. Robotic therapy for chronic motor impairments after stroke: follow-up results. Arch Phys Med Rehabil. 2004;85:1106-11.
27. Stein J, Krebs HI, Frontera WR, Fasoli SE, Hughes N. Comparison of two techniques of robot-aided upper limb exercise training after stroke. Am J Phys Med Rehabil. 2004;83:720-8.
28. Daly JJ, Hogan N, Perepezko EM, Krebs HI, Rogers JM, Goyal KS, et al. Response to upper-limb robotics and functional neuromuscular stimulation following stroke. JRRD. 2005;42(6):723-36.
29. Lo AC, Guarino PD, Richards LG, Haselkorn JK, Wittenberg GF, Federman DG, et al. Robot-assisted therapy for long term upper-limb impairment after stroke. N Engl J Med. 2010;362(19):1772-83.
30. Volpe BT, Lynch D, Rykman-Berland A, Ferraro M, Galgano M, Hogan N, et al. Intensive sensorimotor arm training mediated by therapist or robot improves hemiparesis in patients with chronic stroke. Neurorehabil Neural Repair. 2008;22:305-310.
31. Lum PS, Burgar CG, Shor PC, Majmundar M, Loss MV. Robot-Assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke. Arch Phys Med Rehabil. 2002;83:952-9.
32. Husman SJ, Scott KM, Reinkensmeyer DJ. A Randomized controlled trial of gravity-supported, computer-enhanced arm exercise for individuals with severe hemiparesis. Neurorehabil Neural Repair. 2009;23:505-513.
33. Langhammer B, Stanghelle JK. Exercise on a treadmill or walking outdoors? a randomized controlled trial comparing effectiveness of two walking exercise programmes late after stroke. Clin Rehabil. 2010;24: 46-54.
34. Peurala SH, Tarkka IM, Pitkanën K, Sivenius J. The effectiveness of body weigth-supported gait training and floor walking in patients with cronic stroke. Arch Phys Med Rehabil. 2005;86:1557-64.
35. Visintin M, Barbeau H, Bitensky KN, Mayo NE. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. Stroke. 1998;1122-8.
36. Marigold DS, Eng JJ, Dawson AS, Inglis JT, Harris JE, Gylfadóttir S. Exercise leads to faster postural reflexes, improved balance and mobility, and fewer falls in older persons with chronic stroke. J Am Geriatr Soc. 2005;53:416-423.
37. Tung FL, Yang YR, Lee CC, Wang RY. Balance outcomes after additional sit-to-stand training subjects with stroke: a randomized controlled trial. Clin Rehabil. 2010;24:533-542.
38. Wit DCM, Buurke JH, Nijlant JMM, Ijzerman MJ, Hermens HJ. The effect of an ankle-foot orthosis on walking ability in chronic stroke patients: a randomized controlled trial. Clin Rehabil. 2004;18:550-7.
39. Sheffler LR, Hennessey MT, Naples GG, Chae J. Peroneal nerve stimulation versus an ankle foot orthosis for correction of footdrop in stroke: impact on functional ambulation. Neurorehabil Neural Repair. 2006;20:355-60.
40. Chen C, Hong W, Wang C, Chen C, Wu K, Kang C, et al. Kinematic features of rear-foot motion using anterior and posterior ankle-foot orthoses in stroke patients with hemiplegic gait. Arch Phys Med Rehabil. 2010;91:1862-68.
41. Thijssen DH, Paulus R, Uden CJ, Kooloos JG, Hopman MT. Decreased energy cost and improved gait pattern using a new orthosis in persons with long-term stroke. Arch Phys Med Rehabil. 2007;88:181-86.
42. Shamay SMNG, Christina WY. Hui-Chan: does the use of TENS increase the effectiveness of exercise for improving walking after stroke. A randomized controlled clinical trial. Clin Rehabil. 2009;23:1093-1103.
43. Shamay SMNG, Hui-Chan CWY. Transcutaneous electrical nerve stimulation combined with task related training improves lower limb functions in subjects with chronic stroke. Stroke. 2007;38;2953-9.
44. Mesci N, Ozdemir F, Kabayel DD, Tokuc B. The effects of neuromuscular electrical stimulation on clinical improvement in hemiplegic lower extremity rehabilitation in chronic stroke: a single-blind, randomised, controlled trial. Disability Rehabil. 2009;31(24):2047-54.
45. Bakhtiary AH, Fatemy E. Does electrical stimulation reduce spasticity after stroke? A randomized conrolled study. Clin Rehabil. 2008;22:418-25.
46. Chen SC, Chen YL, Chen CJ, Lai CH, Chiang WH, Chen WL. Effects of surface electrical stimulation on the muscle-tendon junction of spastic gastrocnemius in stroke patients. Disabil Rehabil. 2005;27(3):105-10.
47. Kim JH, Jang SH, Kim CS, Jung JH, You JH. Use of virtual reality to enhance balance and ambulation in chronic stroke: a doble blind, randomized controlled study. Am J Phys Med Rehabil. 2009;88(9):693-701.
48. Sung H, Sung Ho Jang, Yun-Hee Kim, Mark Hallett, Sng Ho Ahn, Yoong-Hyun Kwon, et al. Virtual reality-induced cortical reorganization and associated locomotor recovery in chronic stroke: an experimenter-blind randomized study. Stroke. 2005;36;1166-71.
49. Mirelman A, Patritti BL, Bonato P, Deutsch JE. Effects of virtual training on gait biomechanics of individuals post-stroke. Gait Posture. 2010;31:433-7.
50. Connelly L, Jia Y, Toro ML, Stoykov ME, Kenyon RV, Kamper DG. A pneumatic glove and immersive virtual reality environment for hand rehabilitative training after stroke. IEEE Trans Neural Syst Rehabil Eng. 2010;18(5):551-9.
51. Saposnik G, Teasell R, Mamdani M, Hall J, Mcllroy W, Cheung D, et al. Effectiveness of virtual reality using wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. Stroke. 2010;41(7):1477-84.
52. Lam YS, Man DW, Tam SF, Weiss PL. Virtual reality training for stroke rehabilitation. NeuroRehabilitation. 2006;21(3):245-53.
53. Yip BC, Man DW. Virtual reality (VR) based community living skills training for people with acquired brain injury: a pilot study. Brain Inj. 2009;23:(13-14):1017-26.
54. Yang YR, Tsai MP, Chuang TY, Sung WH, Wang RY. Virtual reality-based training improves community ambulation in individuals with stroke: a randomized controlled trial. Gait Posture. 2008;28(2):201-6.
55. Rand D, Katz N, Weiss PL. Intervention using the VMall for improving motor and functional ability of the upper extremity in post stroke participants. Eur J Phys Rehabil Med. 2009;45(1):113-21.
56. Broeren J, Claesson L, Goude D, Rydmark M, Sunnerhagen KS. Virtual rehabilitation in an activity centre for community-dwelling persons with stroke. The possibilities of 3-dimensional computer games. Cerebrovasc Dis. 2008;26(3):289-96.
57. Boian R, Sharma A, Han C, Merians A, Burdea G, Adamovich S, et al. Virtual reality-based post-stroke hand rehabilitation. Stud Health Technol Inform. 2002;85:64-70.
58. Mead GE, Greig CA, Cunningham I, Lewis S, Dinam S, Saunders DH, Phil M, Fitzsimons C, Yong A. Stroke: a randomized trial of exercise or relaxation. J Am Geriatr Soc. 2007;55:892-99.
59. Intiso D, Santilli V, Grasso MG, Rossi R, Caruso I. Rehabilitation of walking with electromyographic biofeedback in foot-drop after stroke. Stroke. 1994;25 (6):1189-92.
60. Moreland JD, Thomson MA, Fuoco AR. Electromyographic biofeedback to improve lower extremity function after stroke: a meta-analysis. Arch Phys Med Rehabil.1998;79:134-40.