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ORIGINAL ARTICLE

Traumatic brain injury: rehabilitation

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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:

Question 1 - (Brain Injury OR Brain Injuries OR Traumatic Brain OR Head Injury) AND (stretch OR exercises);

Question 2 - Brain injuries AND (persistent vegetative state OR coma) AND (sensory stimulation OR multisensory stimulation OR sensory rehabilitation OR feedback, sensory OR sensation);

Question 3 - Brain Injuries AND (Kinesiotherapy OR Physical Modalities OR Rehabilitation OR Early Intervention);

Question 4 - Brain injuries AND (Exercise OR exercise therapy OR physical fitness OR sports medicine OR physical endurance OR physical conditioning OR exercise tolerance);

Question 5 - (Brain Injury OR Brain Injuries OR Traumatic Brain OR Head Injury) AND (Cognitive Therapy OR Cognitive Rehabilitation) AND (Function);

Question 6 - Brain Injuries AND (Virtual Reality OR Virtual Environment OR Virtual Rehabilitation);

Question 7 - (Brain Injuries) AND (Exercise Therapy) AND (Posture OR Setting Position);

Question 8 - Brain Injuries AND (body weight support OR ambulation training OR partial weight bearing);

Question 9 - (Brain Injury OR Brain Injuries OR Traumatic Brain OR Head Injury) AND (Activities Daily Living OR Activities Daily Life);

Question 10 - (Brain Injury OR Brain Injuries) AND (Physical Therapy Modalities);

Question 11 - (brain Injuries) AND (Intensive Rehabilitation OR Rehabilitation OR Physical Therapy Modalities);

Question 12 - (brain injuries OR brain injury OR hemiplegia OR upper extremity OR upper limb) AND (Orthotic devices OR orthosis OR splint OR splinting);

Question 13 - (brain injuries OR brain injury OR hemiplegia OR upper extremity OR upper limb) AND (Functional Electrical Stimulation);

Question 14 - (brain injuries OR brain injury OR hemiplegia OR upper extremity) AND (electromyographic biofeedback OR biofeedback OR Biofeedback, Psychology);

Question 15 - Brain Injuries AND (Orthotic Devices OR Lower Extremity OR ankle-foot orthosis OR Neuroprosthesis OR peroneal functional electrical stimulation);

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 rehabilitation of people with craniocerebral trauma sequelae.

CONFLICTS OF INTERESTS:

There are no declared conflicts of interests.

INTRODUCTION

The *Brain Injury Association* - (BIA) (2000) defines TBI as brain injury, neither degenerative nor congenital, caused by external physical force. Such a lesion can produce altered or diminished state of conscience, causing disabilities on cognitive, behavioral, emotional, or physical performances. TBI is normally caused by a dynamic load or impact to the head, resulted from localized shock or from sudden movements produced by shock in other parts of the body. This load can result in any combination of compression, expansion, acceleration, deceleration, and rotation of the brain inside the cranium[1] **(D)**.

Both the depth and the duration of coma are being considered as severity indices of TBI, which can be characterized as: mild, i.e., when the trauma-induced physiological disorder of brain function, as manifested by at least one of the symptoms of each period of loss of conscience or memory; initial score in the Glasgow Coma Scale - from thirteen to fifteen; moderate; initial score of nine to twelve in the Glasgow Coma Scale; one to twenty-four-hour post-traumatic amnesia; and severe loss of conscience for over six hours; initial score eight or less in the Glasgow Coma Scale[2] **(D)**.

The cognitive level represented by the state of agitation or inapropriatedness and functional capability can be evaluated by the *Rancho Los Amigos Scale*, divided into ten levels which assign values to the different levels of brain function, according to the patient's reaction to external stimuli[3] **(D)**.

Traumatic brain injury can cause variable degrees of brain injury and initiate several events that result in cellular damage. Brain injuries can be derived from open or closed trauma, and may be classified as focal or diffused. Focal brain injuries are characterized by being, in general, macroscopic and limited to a determined area, as consequence of localized trauma, the deficits deriving from this trauma are similar to those observed in patients with EVA. Diffuse brain injuries, on the other hand, are associated with brain diffuse dysfunction[2,3] **(D)**.

Such brain injuries caused by TBI can result in physical deficits such as plegia that can involve the limbs, tone alteration, ataxia, sensory disorders, and impaired postural control. They can also cause speech disorders; cognitive deficit that lead to attention and concentration alterations, learning disabilities, objects recognition, and spatial relations disorder; also behavioral deficits such as emotional lability, aggressiveness, impulsiveness, disorientation, agitation, irritability, low frustration threshold, and sexual disinhibition[4] **(D)**.

Due to its high physical morbidity and devastating social consequences, TBI is today a critical problem faced by the healthcare systems. If it is taken into account that the average age of TBI victims is below thirty-eight years, it can be observed that this condition presents great socioeconomic impacts to the society[5] **(D)**.

Rehabilitation includes four function domains; physical, mental, affective, and social. Physical function refers to sensorimotor skills required in the performance of activities of daily life and instrumental activities, which are advanced skills and considered vital for the individual's independence within the community. Mental function is related to the individual's intelectual and cognitive capabilities; the affective function regards affective capabilities and coping strategies in dealing with problems and difficulties, and lastly, social function refers to the ability to interact with other people in a successful manner, to the performance of social roles and obligations[6] **(D)**. Thus, rehabilitation services organized with multiprofessional teams are required to guide treatment planning and to promote the approach of all these aspects[5] **(D)**.

1. Does physical rehabilitation using stretching or exercises promote functional independence to people with traumatic brain injury sequelae?

The use of wrist stretching exercises with protocol with four-week duration performed in adult population with hemiparesia from Encephalic Vascular Accident and extensive area Encephalic Vascular Accident, such as brain injury, incapable of actively extending the affected wrist putting it in neutral position, the maximum degree of extension was kept after the four-week period compared to the control group, which performed only conventional rehabilitation without stretching of wrist and fingers, which reduced this amplitude a little, but was not significant ($p < 0.09$). After four weeks of intervention there was improvement in the activity of the limb on the experimental group and it remained the same in the control group, but the difference also was not significant ($p = 0.10$); both groups maintained similar responses to the first assessment in the fifth week, without performing stretching exercises, and in the ninth week with the resuming of the stretching exercises on both groups; no improvements were observed either in the level of pain, in none of the groups along the whole period of intervention ($p = 0.78$)[7] **(A)**.

Recommendation

The use of stretching exercises in an Encephalic Vascular Accident population did not present results that reinforce functional gains in the performance of this practice. However, few studies regarding the use of stretching exercises in hemiplegic population and none specific to traumatic brain injury population were found, which demonstrates the need to amplify researches regarding this practice[7] **(A)**.

2. Is sensory stimulation in comatose TBI patients effective for the improvement of conscience level?

Patients in coma state after suffering traumatic brain injury from auto-accidents with Glasgow Coma Scale equal or lower than eight, all males aged between eighteen and fifty-three years, when submitted to a sensory stimulation program; tactile, auditory, olfactory, gustatory, and visual with twenty-minute sessions three times a day, did not present improvement in conscience state when assessed in the following aspects: catecholamine level, serotonine, acetylcholinesterase, 3-metoxy; 4-hydroxyphenylglycol, heart rate, and skin conduction, but, when compared to patients with routine care without sensory stimulation ($p > 0.05$)[8] **(B)**.

On systematic review including three randomized and non-randomized clinical essays. Only one clinical essay was randomized and the measurements used were different among the studies, therefore, it was not possible to make any quantitative data synthesis[9] **(B).**

Recommendation

Sensory stimulation on adult male patients with TBI does not result in improvement of conscience level. However, there is no specific conclusion and the results are questionable[8,9] **(B)**.

3. Does early rehabilitation promote the recovery of motor function?

In a rehabilitation program, patients were divided into three groups, up to six months from injury, six to twelve months from injury, and over twelve months from injury, all of the groups presented improvements between admittance and discharge. However, the group that had early rehabilitation, that is, up to six months from injury, had better results in reduction of disability, independence, home integration and productivity ($p < 0.001$), but kept improving after discharge. Total community integration score and home integration. These patients' recovery continued even after discharge[10] **(B)**.

An individual early rehabilitation program, started from two to eight weeks by a qualified rehabilitation staff, for TBI patients, does not result in improvement when compared to a group that did not receive early intervention regarding satisfaction, quality of life and health, and community integration at home and family life, social activity, productivity, and leisure activity. After one year from injury the symptoms were the same than before the injury, the SF-36 score was the same or higher than the reference group[11] **(B)**.

A systematic Cochrane review based on the Specialist Neurorehabilitation Services in the United Kingdom in 2005 analyzed randomized and controlled studies of different rehabilitation models. The analysis of fourteen randomized and controlled studies of different rehabilitation models, with a total of 2004 patients, observed evidence, clinical study, that rehabilitation can be more effective when started within one year of brain injury. In this review, in five studies with strong evidence, class A, with a total of 3780 patients, the post-acute early rehabilitation with a multidisciplinary team, leads to better results and shorter time of internment. Over 6600 patients in total were analyzed, however, there was no moderate evidence, class B, of cost-benefit by reducing internment time, due to early intensive and coordinated rehabilitation. In strong evidence, class A, specialized services and hospital internment services, prove that rehabilitation can reduce the need of continued care, with potential cost savings which compensated the initial investment in rehabilitation. There are also evidences of cost-benefit with the return to paid work, in which the paid worker's salaries exceeds the intervention cost, with overall gain for the taxpayer. The strong evidence of gains attained in early rehabilitation notwithstanding, the studies could not prove the impact of early or late rehabilitation, the effect of specialised programs, e.g., professional or neuro-behavioral rehabilitation, or cost-effectiveness[12] **(B)**.

Recommendation

A rehabilitation program started from two weeks to six months of injury is more effective in the motor recovery and shortens the internment period, and also improves the sequelae prognosis. However, a program started from two to eight weeks by a qualified rehabilitation team, for TBI patients, did not prove the difference between an early start and a rehabilitation start after one year from injury, because the patients analyzed in this study did not report improvement of sequelae, thus generating controversy in the investigations[10-12] **(B)**.

4. In TBI patients, does aerobic physical exercise improve functional performance and cardiovascular conditioning?

In patients with TBI sequelae, aged sixteen to sixty-five years, an aerobic training, in lower limb cycle ergometer, of three and a half hours a week during twelve weeks, with 50 rpm and from 60% to 80% of HRmax, is more effective in the improvement of the peak work rate, when compared to relaxation sessions ($p = 0.02$). However, this result is not maintained after twelve weeks from finishing the program, with reduction of 4.41 W (+/±/-. 67) to 4.38 W (+/±/-. 61). No improvement is verified either in the functional aspects, mobility, and psychological function[13] **(A)**.

In patients capable of walking independently with speed equal or higher than 1 m/sec, who perform three weekly walk or light run sessions for twenty minutes, associated with muscular strengthening exercises, during twelve weeks, improve cardiovascular resistance, with increasing of speed in 0.9m/sec (equivalent to 1 MET; $p = 0.01$). Each session must include five minutes of warm-up, twenty minutes of strength training with quadriceps, plantar flexors, abdominal, pectorals, triceps, trunk extensors, and with two series of fifteen repetitions or three series of ten repetitions totalling 180 repetitions and, later, thirty minutes of moderate intensity cardiorespiratory training, the patient must be able to breathe and speak without difficulty. At the end, another five minutes for cooling. For these exercises, the results are the same as when performed under professional supervision or when oriented for performance at home using pictures and written instructions[14] **(B)**.

The aerobic exercise training associated with strengthening exercises in therapeutic pool, with duration of eight weeks, three sessions a week, shows improvement in the lower limb cycle ergometer submaximal test ($p < 0.05$)[15] **(B)**.

Recommendation

Aerobic physical activity, e.g., ergometric bicycle, in patients with traumatic brain injury, during three and a half hours a week over the period of twelve weeks with 50 rpm and 60% to 80% of maximum HR, improves cardiovascular conditioning, but does not result in recovery of functionality and mobility. Aerobic physical activity, walk or light run, associated with muscular strengthening in three hours a week for twelve weeks improves cardiovascular conditioning both when performed under supervision and when oriented at home. Aerobic exercise with muscular strengthening performed in therapeutic pool also results in the same benefits[13-15] **(A,B)**.

5. Does cognitive rehabilitation provide functional independence to people with traumatic brain injury-induced cognitive function deficit?

Didactic cognitive rehabilitation in a specific one and a half to two hour-program, daily, during twenty to sixty days associated with a two to two and a half-hour daily occupational and physical therapy program for the same period, for adults with TBI sequelae, cognitive alterations, results in improvement in functional performance. If compared to functional experiential rehabilitation associated with an occupational and physical therapy program, both programs in the same intervention period, greater gains were observed in the patients that received didactic cognitive rehabilitation. After intervention, there was improvement in the return to work or school ($p < 0.05$); there was improvement in independence for activities of daily life ($p < 0.05$); there was improvement in the cognitive FIM ($p < 0.05$); there was improvement in memory after one year follow-up ($p < 0.05$)[16] **(B)**.

Recommendation

Didactic cognitive rehabilitation in a specific one and a half to two hour-program, daily, during twenty to sixty days associated with a two to two and a half-hour daily occupational and physical therapy program for the same period, for adults with TBI sequelae, cognitive alterations, results regarding improvement in functional performance.[16] **(B)**.

6. Does the use of virtual reality in people with traumatic brain injury sequelae promote beneficial results with improvement of motor and/or cognitive function?

Patients with traumatic brain injury who performed for at least four weeks, three times a week in an exhaustion level ranging from ten to twelve in the Borg scale and in average for more than twenty-five minutes, lower limb cycle ergometer associated with different environments and tasks in virtual reality, improved visual and auditory learning skills (1st to 5th session: $p < 0.05$), the digital symbol coding task ($p < 0.01$) and immediate retention of visual memory task ($p < 0.05$), which demonstrates associations between shapes and figures. Increased the exercise level ($p < 0.01$) and distance covered ($p < 0.001$). There was increase in the scores obtained in attention and processing, and visual and verbal learning tests when compared to the control group ($p < 0.05$). There were no changes for complex figure and logical memory demonstrating that learning is more related to work memory[17] **(B)**.

In a review that included randomized, almost randomized, pre and post-test studies, and case studies, twenty-two articles were found, twenty-one of those with EVA and one with TBI. It demonstrated that virtual reality rehabilitation of UL in Acquired Brain Injury is exploratory and that the studies are conducted, exclusively, in EVA demonstrating the need of including the TBI population. Most articles were rated very close to the cutoff for classification as poor, emphasizing the need of care when implementing virtual reality prioritizing more substantial evidence[18] **(B)**.

Recommendation

The use of virtual reality associated with lower limb cycle ergometer three times a week, in average for more than twenty-five minutes reaching exhaustion level ranging from ten to twelve in the Borg Scale, for at least four weeks, promotes improvement in the exercise performance and some cognitive aspects. The use of virtual reality in upper limb rehabilitation in patients with TBI is not fundamented and its application must be careful[17,18] **(B)**.

7. Does postural changes training improve functional performance?

A conventional rehabilitation program within a four-week period, associated with a 100-repetition sit-to-stand postural change training in chair with 110% of patient leg height changing to 90% of patient leg height by the end of the fourth week, and sixty repetitions climbing 10 cm-high steps, during five days a week for patients with severe traumatic brain injury of up to one year of injury, that have no orthopaedic conditions that prevent training, lower than two score in the *Motor Assessment Scale* for the sit-to-stand training, and capable of understanding simple orders, and sit at the chair with plantigrade support, promotes the improvement of functional performance, with the 1735-repetition sit-to-stand result, with average eighty-seven repetitions/day, and at 831 repetitions of mounting steps with average forty-two repetitions/day ($p = 0.03$), with performance time ranging from ten to sixty minutes, and increase in the VO_2 peak ($p < 0.05$) when compared solely to a conventional rehabilitation program[19] **(B)**.

Recommendation

The oriented postural change training, sit-to-stand, and step climbing, associated with a conventional rehabilitation program in patients with severe traumatic brain injury, during four weeks for five days a week with 100 repetitions/day and sixty repetitions/day respectively, results in better task functional performance[19] **(B)**.

8. Is body-weight-supported treadmill gait training in patients with traumatic brain injury sequelae better in comparison with training without body-weight support?

Treadmill gait training with initial 30% of the body weight suspension during fifteen minutes within a total thirty-minute session, twice a week for fourteen weeks associated with conventional physical therapy in post-TBI chronic ataxic patients, does not promote improvement in the *Functional Ambulation Category* (FAC), Time Up and Go and *Functional Reach Test,* and in the gait speed, but it improves step width ($p = 0.036$). However, overground gait training presents greater reduction in step asymmetry ($p = 0.011$) than treadmill training[20] **(B)**.

Body-weight-supported treadmill gait training associated with conventional physical therapy, over eight weeks, with adult patients presenting TBI sequelae, results in improvement in functional gait according to *Standing Balance Scale*-SBC ($p < 0.01$); FAC ($p < 0.01$); *Gross Motor Subscale* ($p < 0.01$); *Rivermead Mobility Index*-RMI ($p < 0.01$), and *Functional Independence Measure*-FIM/FAM ($p < 0.01$). However, when compared to conventional physical therapy treatment without body-weight support it does not present significant difference in the average scores of SBC ($p < 0.687$); FAC ($p < 0.922$); GMS ($p < 0.927$); RMI ($p < 0.855$) and FIM/FAM (< 0.9753) tests[21] **(B)**.

Recommendation

Body-weight-supported treadmill gait training associated with conventional physical therapy in patients with TBI sequelae demonstrates it is equally or less effective for *Balance* and other gait-related aspects improvement than overground grait training associated with conventional physical therapy[20,21] **(B)**.

9. Does activities of daily life functional training with people with traumatic brain injury sequelae impact the subjects' occupational performance?

The upper limb skill training, functional training, in a specific program, once a week for three consecutive weeks, associated with conventional rehabilitation, physical therapy, and occupational therapy, for adults with TBI sequelae, hemiparesia, results in improvement of functional performance. After intervention, there was improvement in the time of completion of the tasks proposed in the program ($p < 0.05$); there was improvement in unilateral and bilateral activities ($p < 0.05$); there was maintenance of the gains, verified after one-year follow-up ($p < 0.05$); and compared to the same intervention with *feedback* to patients about their performance, there was no significant difference. Compared to conventional rehabilitation intervention, of physical therapy and occupational therapy, in the same period, greater gains were observed in the patients that received training[22] **(B)**.

Recommendation

The upper limb skill training, functional training, in a specific program, once a week for three consecutive weeks, associated with conventional rehabilitation, physical therapy and occupational therapy, for adults with TBI sequelae, promotes benefits regarding functional performance[22] **(B)**.

10. Does constraint-induced therapy benefit patients with traumatic brain injury-induced hemiplegia?

Constraint-induced movement therapy with protocol with three-week duration with population with hemiparesia due to Encephalic Vascular Accident capable of actively extending, at least, 10° in the matacarpophalangeal and interphalangeal joints and 20° in the wrist, in addition to spasticity score lower than three in the Modified Ashworth Scale, presents improvement of scores in the assessment scales *Fugl-Meyer Assessment* (FMA) ($p < 0.001$), *Motor Activity Log* (MAL) *amount of use* (AOU) ($p < 0.012$) and *quality of movement* (QOM) ($p < 0.005$) from pre to post-treatment, and also presents superior results compared to conventional occupational therapy and upper limb bilateral motor training performance post-treatment with the same type of population[23] **(A)**.

Constraint-induced movement therapy with modified protocol with ten-week duration with population with hemiparesia due to Encephalic Vascular Accident with the following characteristics: Brunnstrom stage over III for proximal and distal parts of the UULL, affected upper limb non-excessive spasticity with maximum score of two degrees in the Modified Ashworth Scale, presents improvement of scores in the assessment scales *Fugl-Meyer Assessment* (FMA) ($p = 0.002$), Action Research Arm (ARA) ($p = 0.001$), and *Motor Activity Log* (MAL) *amount of use* (AOU), and *quality of movement* (QOM) from pre to post-intervention, and also presents superior results when compared to conventional therapeutic intervention: physical therapy and occupational therapy, proprioceptive neuromuscular facilitation, techniques, with emphasis in functional tasks, stretching of the affected limb and compensatory techniques using the less affected side, and non-interventional, control group, conducted with the same type of population[24] **(B)**.

Recommendation

Constraint-Induced Movement Therapy (CI or CIMT) promotes benefits to the population with hemiparesia with six months or more of ischemic or hemorrhagic Encephalic Vascular Accident and that present minimum recommended movement and spasticity degree according to the protocols used. No studies were found that show the use of CIMT in the population with sequelae from Traumatic Brain Injury (TBI), however, both populations present similar motor conditions according to injury area, therefore, this population with sequelae from TBI could benefit from the use of this type of therapy[23,24] **(A,B)**.

11. Does intensive physical therapy promote motor function recovery?

A physical therapy and occupational therapy program, with 6.4 hours/week of training for patients with traumatic brain injury, EVA and multiple sclerosis, is more effective in the recovery of motor functions, which reduces in fourteen days ($p < 0.001$) the patients' permanence period in a rehabilitation unit than 4.9 hours/week[25] **(B)**.

Intensive intervention of a physical therapy program performed in 9.66 hours/week (580 minutes), with patients after six months from a traumatic brain injury anticipates the functional gains sphincter control ($p = 0.003$) and transferences ($p = 0.05$) diminishes internment days, average sixty-two days ($p = 0.03$) than 6.7 hours/week (402 minutes)[26] **(A)**.

Rehabilitation training with 4 hours/day during five days of the week for patients with moderate to severe traumatic brain injury in the subacute phase, results in a greater recovery of motor function in the third month of rehabilitation ($p = 0.016$) than a 2 hour/day training during five days of the week[27] **(B)**.

Recommendation

Intensive rehabilitation training, ranging from 6.4 hours/weekly to 20 hours/weekly, improves functional results of patients with TBI, especially, in the first months of the motor recovery process[25-27] **(B,A,B)**.

12. Does the use of static orthosis for the positioning of wrist and fingers in spastic upper limb of people with hemiplegia due to traumatic brain injury promote maintenance of active and passive amplitudes of movement, improve spasticity/contractures?

The use of orthosis positioning wrist in extension with over 45° and matacarpophalangeal and interphalangeal joints in extension, compared to the use of orthosis positioning the wrist betwe,33en 0° to 10°, both for twelve hours a day during four weeks of intervention associated with conventional rehabilitation and stretching exercises for the wrist and finger flexor musculature, isolatedly, maximum ten minutes a day, presented in average, a moderated loss of amplitude of movement (average of 16.7°; 15.1°) over six weeks, in the subacute phase. However, no differences were observed between groups, or when compared to patients that received only conventional rehabilitation with stretching exercises for flexor muscles[28] **(A)**.

Upper limb motor training with stretching exercises, individually, for approximately thirty minutes a day, five days a week, associated with the use of orthosis immobilizing hand, wrist and fingers in functional position (10° to 30° wrist extension) for a maximum period of twelve hours, each night during four weeks of intervention, did not present gains regarding the amplitudes of movement when compared to the intervention on patients that received only the wrist and fingers musculature stretching exercises program[29] **(A)**.

Studies showed that regardless of the type of upper limb orthosis, duration, positioning, the benefit regarding deformity prevention, gain or loss in the amplitudes of movement, improvement in contractures and spasticity cannot be affirmed. In twenty-one selected articles, five randomized, within a search with 108, which analyzed the effect of the use of orthosis in upper limbs of patients with hemiplegia, showed heterogeneous results regarding the expected effects in improvement of amplitudes of movement, improvement of pain, improvement of contractures and spasticity. However, this analysis was harmed, largely, due to the lack of randomized studies with controlled essays. Neither affirming nor denying the effectiveness of upper limb orthoses in hemiplegic patients[30] **(B)**.

Recommendation

The use of upper limb orthosis in patients with hemiplegia due to traumatic brain injury, positioning wrist and fingers in the functional position (10° to 30° of wrist extension) or wrist in extension(> 45°) for twelve hours a day, during four weeks does not seem to promote the maintenance of amplitudes of movement of the flexor muscles of the wrist and fingers in patients with hemiplegia due to traumatic brain injury. However, there are not enough evidence to justify, refute, or reinforce this procedure[28-30] **(A,B)**.

13. Does the use of FES in spastic upper limb of people with traumatic brain injury-induced hemiplegia improve spasticity?

Rehabilitation strategies that combine type A botulinum toxin injections and task therapy with the use of FES are viable and effective in the improvement of upper limb regarding motor function and spasticity reduction in patients with chronic spastic hemiparesia, due to TBI or EVA. All participants had a minimum of six months of unilateral spastic hemiparesia and received at least two applications of type A botulinum toxin for the treatment of spasticity. The subjects had pre-intervention scores of two or higher in the Modified Ashworth Scale in at least one of the following muscle groups: flexors of the wrist or flexors of the fingers. Each functional electrical stimulation cycle consisted of a five-second period of stimulation of the extensors, followed by a five-second period of stimulation of the flexors and a rest period of two seconds, and the FES group participants were instructed to coordinate their actions with the stimulation pattern of the device used, in order to synchronize the user's intention with the FES assistance. The intervention for both groups included a home exercise program, oriented by an occupational therapist, that demanded a total sixty-minute practice of daily tasks, during twelve weeks using a padronized protocol without constraint of the preserved upper limb[31] **(B)**.

The results for motor function and spasticity were evaluated at the start, two weeks before, and six and twelve weeks after the interventions. The scores of items improved from the start until week six ($p = 0.005$), but did not remain significant after twelve weeks in the group that received FES intervention. However, there were no significant differences between the FES and non-FES groups by any variable result over time[31] **(B)**.

Recommendation

Rehabilitation strategies that combine type A botulinum toxin injections and task therapy associated with the use of Functional Electrical Stimulation are viable and effective in the improvement of upper limb motor function and spasticity reduction in patients with chronic spastic hemiparesia, due to TBI or EVA. However, the FES protocol used in the study did not potentize the gains obtained with the combination of type A botulinum toxin associated with task practice in the home environment over time[31] **(B)**.

14. Is the use of *biofeedback* on the affected upper limb of people with traumatic brain injury-induced hemiplegia effective in the improvement of motor control?

The use of *biofeedback* in the radial extensor muscle of the wrist and in the extensor muscle of fingers in patients with hemiparetic upper limb, with duration of twenty minutes a day, five days a week, associated with Brunnstrom-based neurological rehabilitation program with duration of forty-five minutes over twenty days is effective in the hand functional improvement when compared to patients that received the *biofeedback* placebo program. However, in both groups there was improvement in the active movement for wrist extension after the intervention: (*biofeedback* group $p < 0.001$; placebo group $p < 0.05$). *Biofeedback* showed potential gains ($p < 0.001$) when compared to the placebo ($p < 0.01$), and the difference between groups is favourable to the treatment with use of *biofeedback* ($p < 0.001$)[32] **(B)**.

Motor control training for postural symmetry adjustment, with the performance of pushing and pulling a load task, by means of upper limb resistance movements, performed standing on the modified biofeedback system for postural control, consisting of a work table with adjustable height, postural correction mirror, forearm support system, suspension and neutral position hip fixation system, performed for sixty minutes each session, five days a week over four weeks, reduces the postural asymmetry percentage in hemiplegic patients from 17.2 ± 10.8% to 3.5 ± 2.2%, when compared to hemiplegic patients that had the same postural control training in a conventional biofeedback system (from 17.0 ± 10.0% to 10.1 ± 6.4%) being ($p = 0.003$), even though both demonstrated positive results when associated with conventional therapeutic program protocols[33] **(B)**.

Facilitation of the triceps muscle strategy, in training with the use of biofeedback, in order to evaluate the isotonic contraction of the triceps and biceps muscles during the performance of three functional tasks in the following order of degree of difficulty: elbow extension with gravity elimination; resisted elbow extension with eliminated gravity and 0.68 kg load of resistance; and resisted elbow extension with 0.68 kg load of resistance and shoulder stabilization at 22.9 cm over the table surface. Twenty-five-minute sessions, with three-repetition series for each task, in total ten sessions, in the electromyographical readings of the triceps and biceps muscles during the functional tasks for elbow extension reach considered, separately, in the variables of passive and active amplitude of movement; muscular activity, and movement speed indicated positive results with reduction in the average of EMG activity of the biceps muscle; an increase in the average EMG activity of the triceps muscle, and an increase in average speed during the task, in addition to gains in amplitudes of movement. However, no significant differences were demonstrated when comparing hemiplegic patients that had biofeedback training and those that had training on the same tasks without biofeedback[34] **(B)**.

Recommendation

The use of biofeedback with twenty minutes a day duration, five days a week in combination with neurological rehabilitation demonstrates potential to maximize hand function and motor control in the active movement of the wrist in hemiparetic patients. It also demonstrates potential to increase triceps muscle activity antagonist to biceps hypertonia in twenty-five-minute sessions; also helps in the postural control for asymmetry correction during the performance of tasks in sixty-minute sessions[32-34] **(B)**.

15. What is the best lower limb orthosis to help in the positioning of the foot and in the improvement of gait in TBI patients?

Patients with EVA and TBI with over six months from injury, presenting footdrop, dorsiflexion AOM of at least 0 degrees, capable of walking 10 m without assistance or with a cane and ability to step in several directions were evaluated regarding gait when using a neuroprosthesis and a positioning orthosis (*Ankle Foot Orthosis* - AFO). Before evaluation they had a four-week adaptation period with the neuroprosthesis in which, in the first week, they should use it for one hour, for four hours by the end of the second week and more than six hours by the end of the fourth week and continue using AFO for at least two hours a day in this stage. After the first evaluation the patients were urged to use only the neuroprosthesis and were then reevaluated after another four weeks. After this four-week adaptation period there was no difference in gait when with the neuroprosthesis and with the AFO ($p > 0.05$). After eigth weeks, the neuroprosthesis effect was better than that of the AFO, with reduction in step time ($p < 0.02$), less varying in the non-paretic leg swing time ($p < 0.01$) and improvement in balance ($p < 0.05$), however, there was no change regarding gait speed according to the six-minute test ($p = 0.142$)[35] **(B)**.

Recommendation

The use of a neuroprosthesis in TBI and EVA patients after a four-week adaptation and continuous use for another four weeks promotes improvement to the gait asymmetry in balance, reduction in step time and more symmetric weight discharge when compared to the use of AFO[35] **(B)**.

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