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Original Article

Management of physical neuro-readaptation in subjects with hemiplegic disabilities for social inclusion: a systematic review

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Abstract:
Physical activity has been a point of interest with regard to the motor re-adaptation of those with functional limitations and diseases, being an alternative to pharmacological treatments or other treatments which many times carry negative effects on those who partake. With this in mind, it is fundamental to research the existing literature to understand the different studies and models of physical activity that have been used for the strengthening or re-adaptation of motor capacity of people with hemiplegia, as well as other complementary strategies used to readapt the victims of this traumatic condition. The purpose of this study was to conduct an in-depth analysis of the existing literature and offer a holistic vision of the current status of physical neuroadaptation research in adults with hemiplegic cerebral paralysis. For this purpose, four data bases were used: SCOPUS, Medline, Pubmed, and WOK. Four distinct searches using a combination of the keywords “physical activity”, “hemiplegia”, “ictus”, and “spasticity” was performed. The results showed 71 valid publications between 2003 and 2016. The articles were categorized according to their content. The results revealed that the knowledge about physical neuroadaptation in people with hemiplegic cerebral paralysis are heterogeneous. Themes, presented in order of most found to least found number of publications are: functional re-adaptation methods, limitations to participating in physical activities, the victim’s limitations when participating in physical activity, and factors that influence physical re-adaptation.
Key words*:* Physical Activity, Hemiplegia, Limitations, Cerebral Palsy, Re-adaptation, Systematic review

Introduction

For a number of decades, physical activity has been a point of interest with regards to motor re-adaptation for those with functional limitations and diseases, becoming an alternative to pharmacological treatments or other type of procedure which in many occasions cause negative effects in those involved. Recently, many and very diverse forms of bringing physical activity to the realm of re-adaptation and prevention of injury (Lauersen, Bertelsen & Andersen, 2014; Rössler et al., 2014) have become an indispensable element for motor and functional improvement in people whose motor capacity has been reduced or limited by diseases or accidents.

Today, cerebrovascular accidents and/or injuries are one of the mayor causes of disability in the population, and are provoked by a failure in blood supply to the brain. One of the most damaging consequences of these accidents is cerebral paralysis. Cerebral paralysis describes a groups of developmental disorders in movement and posture, causing activity limitation. Motor skill incapacity are usually accompanied by alterations in sensitive, cognitive, communication, perceptive, and/or behavior abilities (Bax et al., 2005). There are different types of cerebral paralysis, attending to the affected area or to the muscle tone. According to the affected area, we find monoplegia (when only one member is affected), hemiplegia (the second objective of the study, when half of the body is affected), diplegia, (both legs and arms are lightly affected), paraplegia (only both legs are affected), and tetraplegia (both arms and both legs are affected). Spasticity is found according to muscle tone (muscular stiffness), athetosis (slow, involuntary, and awkward movements) or difficulty controlling balance (National Institute Of Neurological Disorders and Stroke, 2016).

When the victim presents this kind of disability, physical activity is considered an effective tool to regain functional capacity by means of favorable physical task, thus increasing the autonomy of the victim, and as a result, quality of life (Ada, Dorsch & Canning, 2006; Davis, 2006; Dobkin, 2004; Dromerick, Lum & Hidler, 2006). Therefore, it is imperative to immerse in the existing literature in order to know the different studies and models of physical activity that have been used in the re-adaptation of victims with hemiplegia along other complementary strategies that have been effective in the re-adaptation of participants.

The present paper offers an analysis of the existing literature by providing a global overview of the current status of the body of knowledge regarding physical neuroadaptation in adults with hemiplegic cerebral

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paralysis. Its objective is to add to the body of knowledge of physical neuroadaptation in people with hemiplegic cerebral paralysis while systematically organizing and making relevant information offered by previous studies.

Material & methods

Procedure

An extensive and exhaustive search in the electric data bases SCOPUS, Medline, Pubmed, and WOK was conducted to identify relevant articles.

Four Boolean searches were conducted in each of the data bases using different combinations with the keywords "physical activity", "hemiplegia", "ictus", and "spasticity". The first search used the key words "physical activity" and "hemiplegia", with the Boolean variable "AND". The second search substituted the word "hemiplegia" for the word "ictus", also utilizing the variable "AND". The third search employed the words "physical activity", "rehabilitation", and "hemiplegia", connected by the Boolean variable "AND". Finally, the fourth search changed "physical activity" for "spasticity" and also made use of the variable "AND".

The researchers employed the snowball technique as they examined the reference list of those already chosen for any possible valid reference. The list of references for each selected article was examined to identify other possible references. The final search was conducted on February 10, 2026.

Data collection

The data collection was conducted by three independent investigators from the University of Sevilla (Spain) and the other from West Virginia University (USA) with experience in the field of disability and physical re-adaptation. All the investigators conducted their search independently then met periodically to discus and come to consensus with regards to the results obtained.

Titles and abstracts of articles found through the four searches were reviewed to eliminate any repeated articles. Next, the entire text of the remaining articles was read carefully to determine if it could be included in the study. The criteria for inclusion was the following: (1) articles in which topics of physical activity, re-adaptation, and hemiplegia appeared on the title, abstract, or as a keyword; (2) articles which were research or revisions; (3) articles published between the years 2003 and 2016 in the areas of medicine, health professions, neuroscience, and nursing; (4) articles written completely or partially in English (at least the abstract); (5) articles that address the adult population (18 years or more).

Evaluation of the quality of methodology

Once the relevant articles for revision were selected, the Jadad scale was systematically utilized to determine the quality of the studies for inclusion and acceptance. The norm established for the selection of articles required each article to receive a score of three or more points, which indicates good quality. The Jadad scale was selected due to its easy design and because it has the ability to provide a global vision of the internal and external validity of the articles included in this systematic revision.

Data analysis

Once the articles were selected, the authors proceeded to retrieve the data. The data was retrieved by two authors and revised by a third. After retrieving the data, discrepancies between the authors were discussed, with the third author who was to settle differences on the basis of their approach. All articles were categorized according to its nature and the personal criteria of the researchers of the study, who then implemented a system of categorization and placed the chosen articles in three categories: (1) limitations in performing physical activity, (2) influencing factors in physical re-adaptation, and (3) methods for functional re-adaptation.

Results/Discussion

The order in which the database search took place was: (1) SCOPUS; (2) Medline; (3) WOK; and (4) Pubmed. In each one of the data bases, four searches were conducted as previously mentioned in the Development section, and in every search initial results were obtained (when introducing the keywords). At a later date, the search criteria was applied to obtain the final results. At the very least, the titles and abstract of articles in the final articles results were read to discard any repetition from previous searches and those not relevant to our topic of investigation. The remaining articles were employed in the elaboration of this paper.

Literature analysis

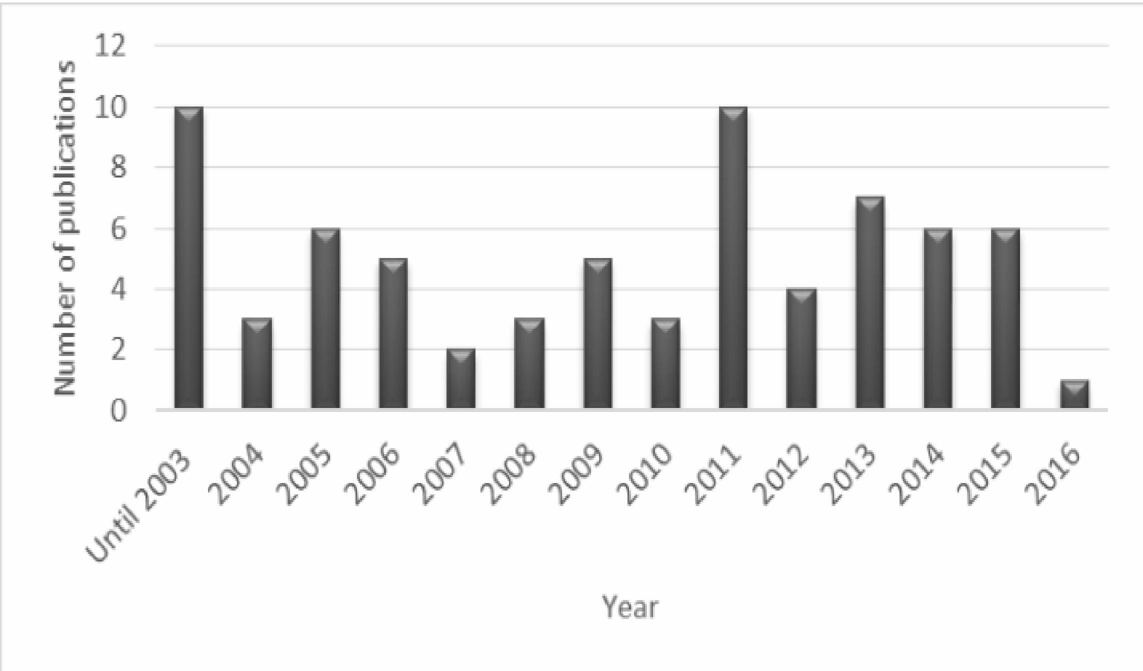
Descriptive analysis. A total of 5,476 articles were obtained in the initial results. This number was reduced to 647 after applying the inclusion criteria. Finally, a total of 62 articles were selected from which an additional nine articles emerged from the revision of the reference list of each article applying the snowball technique using 71 articles as reference (See table 1):

Table 1: Search results

		Initial results	Final results	Chosen papers
SCOPUS	1st search	715	36	8
	2nd search	22	11	2
	3rd search	412	59	9
	4th search	432	59	7
MEDLINE	1st search	577	40	7
	2nd search	13	8	1
	3rd search	437	21	1
	4th search	434	36	6
WOK	1st search	179	101	11
	2nd search	3	0	0
	3rd search	122	67	0
	4th search	170	106	8
PUBMED	1st search	938	40	2
	2nd search	18	6	0
	3rd search	571	34	0
	4th search	433	23	0
Snowball technique				9
Total		5476	647	71

Source: Self made

In regards to the year of publication of the selected articles, it is noticed that most articles are published between the years 2010 and 2016, (See figure 1).



Source: Self made

Fig. 1. Number of publications per year

Regarding the journals in which the studies were published, there is a great variety in the ones that have published the topic under study. In total, there are 40 journals that have published the articles used as references in this review. (See table 2).

All the references employed in this study were analyzed and classified with the previously mentioned themes, as demonstrated in the table below (See table 3).

Table 2. Number of publications per magazine

Title of the magazine	Number of publications per magazine
Journal of Physical Therapy Science	7
Archives of Physical Medicine and Rehabilitation	5
Physical Therapy; Neurorehabilitation and Neural Repair; Journal of Rehabilitation Medicine	4
Topics in Stroke Rehabilitation; NeuroRehabilitation; Stroke	3
Clinical Rehabilitation; Developmental Medicine & Child Neurology; European Journal of Physical and Rehabilitation Medicine; Rev Neurol; Journal of Neuroengineering and Rehabilitation; The American Journal of Occupational Therapy; JNPT	2
Australian Journal of Physiotherapy; Annals of Rehabilitation Medicine; Technology and Health Care; Neurología; The Lancet Neurology; The Journal of the American Society for Experimental Neurotherapeutics; Revista Cubana de Medicina Integral; Scandinavian Journal of Rehabilitation Medicine; Physiotherapy Theory and Practice; American Journal of Physical Medicine and Rehabilitation; Turkish Journal of Physical Medicine and Rehabilitation; Medicina (Kaunas, Lituania); Medicina Clínica; Zeitschrift für Gerontologie und Geriatrie; Complementary Therapies in Clinical Practice; Sensors and Materials; Isokinetics and Exercise Science; Journal of Rehabilitation Research and Development; International Journal of Rehabilitation Research; Journal of Mechanics in Medicine and Biology; Physiotherapy Canada; Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery; Rehabilitation Psychology; Journal of Acupuncture and Tuina Science; British Journal of Sports Medicine; Sports Medicine	1

Source: Self made

Table 3. Categories of the chosen papers

Categories			Number of papers
Limitations in performing physical activity			5
Influencing factors in physical re-adaptation			4
Methods for functional re-adaptation	Activities of daily living	11	62
	CIMT	12	
	FES/NMES	17	
	Other techniques	11	
	Electronic or computer devices	11	

Source: Self made

Limitations in performing physical activity. In their study, Steenbergen, & Gordon (2006) affirm that motor limitation in cerebral hemiplegic paralysis is not only a consequence of disorders in movement execution, but is also caused by disorders in the planning of the same. The same authors state that motor planning implies predicting the future state of the motor system or the consequence of its action. This could be due to a limited ability to integrate sensory information with the motor response of the side affected by hemiplegia. According to these authors, there is recent evidence that suggest that a possible cause of the deficit in motor planning could be deficiencies in motor visualization (which consist in mentally representing movement without any motor gesture), which plays a fundamental roll in the planning process. After obtaining these findings, the authors suggest that the implementation of biannual therapies or a division of movement sequence could be beneficial to the subject.

In their investigation, Cho, Kim & Joo (2012) established that hemiplegia provoked by cerebrovascular accidents affect not just the shoulder affected, but also the unaffected side. The authors also propose that adequate management of muscular spasticity, improved motor recovery, and avoidance of the overuse of the non-affected shoulder should be considered to avoid shoulder problems after a cerebrovascular accidents which lead to hemiplegia.

On the other hand, Yen & Li (2015) share their investigation which offers a different perception of strength and effort in voluntary muscular activation between the affected and the non-affected arm in subjects that have suffered a cerebrovascular accident and present muscular spasticity.

Arterial stiffness has been addressed (Murakami, Kato, Maeda, Takahashi & Furukawa, 2005) by analyzing the baPWV (brachial-ankle Pulse Wave Velocity). The study establishes that in participants affected by hemiplegia, baPWV is significantly greater in the affected side when compared to the non-affected side, possibly to the decrease of arterial extensibility due to paralysis. Nonetheless, the authors affirm that baPWV improves rehabilitation, and such improvement is directly related with an increase in physical activity participation, for which baPWV could be considered an effective index of rehabilitation.

Motoi et al. (2012) evidence that monitoring systems could be useful to evaluate characteristics of movement during the rehabilitation of patients. This way the efficacy of rehabilitation could be quantitatively evaluated. With this in mind, the information gathered up to date could be summarized stating that subjects with hemiplegia who are mobility-impaired due to a deficiency in motor planning and in motor visualization. At the same time, shoulder problems in the affected side as well as in the non-affected side could surface the latter being a result of overuse. This suggest that the implementation of studies addressing the affected member as well as the non-affect , movement divided in parts for an easier assimilation and monitoring of the movement by means of electronic devices are good forms of achieving functional re-adaptation in the participant.

Factors influencing re-adaptation. In his study, Dobkin (2004) proposes that the bases for the acquisition, retention, and recovery of information are the same in a healthy brain as well as in one that has suffered from a cerebrovascular accident, with the exception of the case of the latter in which there are less unaffected nerval pathways. However, experience and training favor physiological and morphological spasticity after a cerebrovascular accident to increase the functional capacity of the participant. (Para conseguir esto y aumentar la capacidad funcional del sujeto.

On the other hand, Estévez-Perera, Coll-Costa & Estévez-Perera (2011) conducted a study to address the satisfaction of the persons with hemiplegia after participating in an individualized physical activity program. A survey was completed by 115 participants to assess opinions regarding their evolution in ADL (Activities of Daily Living), the state of satisfaction while participating in the exercise program and the recovery valorization. Of all the participants, 96.7% evaluated the exercise program as very good, while 3.3% valued the program as good. Of the ADL, recreational walking had the most improvement as identified by 95% of the participants, while 5% chose other activities such as nutrition or personal hygiene. In conclusion, the authors express that the individualized physical activity programs bring about a good level of satisfaction and increases participant’s motivation.

Furthermore, Fernandez-Concepcion et al. (2003) developed a scale to evaluate the quality of life of people whom have suffered a cerebrovascular injury. Several categories are developed in this scale: I. Physical status (17 items); II. Emotional status (13 items); III. Activities of daily living (13 items); IV. Social and familiar functions (13 items); and the following: 1. Physical problems; 2. Communication; 3. Cognition; 4. Emotions; 5. Feelings; 6. Activities of daily living; 7. Familial functions; 8. Social functions.

Finally, Ng & Hui-Chan (2012) analyzed the impact of the strength of the dorsal flexor muscles of the ankle with regards to the participant’s walking capacity. These authors conducted spasticity test of dorsal flexor and plantar flexor musculature of the ankle, and the 6MWT (6-minute Walk Test). The results obtained established the existence of a positive correlation between musculature dorsal flexor strength of the ankle and its walking capacity for which reason strengthening exercises should be included to fortify this musculature if the participants desire to improve their walking capacity.

Methods for functional re-adaptation: Exercises related to activities of daily living. With regards to training programs related to specific activities of daily life, there are different methods to apply this type of program (Davis, 2006; Dromerick et al., 2006; Hariohm & Prakash, 2014; Krutulyte, Kimtys & Krisciūnas, 2002; O'Dell, Kim, Rivera-Finnen & Polistena, 2011; Page et al., 2011; Song, 2015; Timmermans et al., 2014). For example, Page et al. (2011) conducted a case study of a 53 year old man with an affected arm. The intervention consisted of RTP (Repetitive Task-specific Training Program) three days per week for eight weeks incorporating a neurobionics artefact to the training. The participant had suffered the cerebrovascular accident 30 months prior to participating in the training. The results suggest a reduction in the deficiency of the affected arm and an increase in the ability to perform activities included in the RTP and participant satisfaction in his own endurance, strength, daily living performance, functionality, and participation. The results were evaluated using the following tests: FM (Fugl-Meyer Impairment Scale, from Fugl-Meyer, Jääskö, Leyman, Olsson & Steglind, 1975; reelaborated by Duncan, Goldstein, Matchar, Divine & Feussner, 1992), COPM (Canadian Occupational Performance Measure), and SIS (Stroke Impact Scale). The evaluation was conducted before and after the training program.

Davis (2006) conducted a study with the objective of developing and implementation guide for functional training programs of the superior extremity of the body to improve mobility and functionality of these in survivors of cerebrovascular accidents. The first aspect to highlight by this author is that if functional activities are conducted utilizing objects from daily life in an enriched, a multidimensional approximation is produced in the treatment. This type of activity requires a simultaneous utilization of motor control, cognitive, visual, perceptual, sensory, and motor planning. Furthermore, the author affirms the need to consider the infrastructure afforded by the ICF (International Classification of Functioning, Disability and Health) in order to adequately structure the training program. The ICF establishes six components in order to organize an efficient functional training: Health Condition, Participation, Personal Factors, Environmental Factors, Body Functions, Body Structures, and Activities, activities being the crucial factor, and all interrelated among themselves.

In a research conducted by Dromerick et al. (2006), activity based therapies were studied. Three therapies of this type that are further developed are CIMT (Constraint-Induced Movement Therapy, Therapy with limited induced movement), robotic therapy intended for the hemiplegic arm, and ergometer training therapy. These three techniques appear to be effective to produce improvements in the arm and walk functionality. In this study, improvements in muscular resistance training regarding the strength of participants with a cerebrovascular accident, without incrementing the hypertonia provoked by spasticity. Different factors that could be related with improvement on ADL among these are: intervention time post-accident, intensity of intervention, type of intervention, and parameters of training within the session, are also included.

Another intervention compares task-oriented bilateral arm training with repetitive bilateral arm training (Song, 2015). For this, a 12 week training plan takes place (30 minutes per day, five days per week) with two groups composed of 20 people each. Each group performs one of the two methods previously explained. The results are measured through the BBT (Box and Block Test), JBT (Jebsen-Taylor Test), and the MBI (Modified Barthel Index). After 12 weeks of training, significant improvements in both groups were produced and significant differences in both favorable to the groups oriented to the task.

In addition, Hariohm & Prakash (2014) carried out a case study in which the development of a training program oriented to task activities (task-oriented training) and proved its usefulness when it comes to improvements in activities involving profound flexion of the knee. The results obtained were associated with positive changes in functional activity and social participation of the participant.

Other authors who have studied this type of re-adaptation are Krutulyte et al. (2002). In their study, benefits brought about by the combination of physiotherapy and the Bobath method were compared. The Bobath method and the MRP (Motor Relearning Program) method and the combination of physiotherapy and Motor Relearning Program (MRP), to measure mobility, the EFRR (European Federation for Research in Rehabilitation) scale was used and the Barthel Index measured ADL. The results obtained demonstrate that the greatest benefits are obtained when combining physiotherapy with MRP.

A similar investigation (Timmermans et al., 2014) was conducted to compare women in a task-related training with and without robotic assistance (experimental group with robotic assistance and the control group without it). The training took place during eight weeks, four days per week, and two thirty minutes series per day. The results revealed both groups as having improvements but significant differences were not obtained in any of the groups.

Finally, the study of O'Dell et al. (2011) demonstrates that the AMAT (*Arm Motor Ability Test*, from Kopp et al., 1997) has, according to psychometric studies, a good reliability and validity to be used as a measure in the rehabilitation of cerebrovascular accidents, ten ADL are included. Each one composed of 1-3 sub-tasks.

Methods for functional re-adaptation: CIMT. CIMT (Bang, Shin & Choi, 2015; Bonifer & Anderson, 2003; Dobkin, 2004; Dromerick et al., 2006; Page & Levine, 2007; among others) consists on limiting the non-affected arm's functionality in search for better functionality of the affected. This method of training is one of the most efficient in regards to functional activities (Dromerick et al., 2006). For this, the CIMT application consist of promoting the use of the affected superior member during 90% of the wake hours per day thus limiting the movement of the non-affected arm during the 2-3 weeks of using an arm sling, so as to not to interrupt ADL, but can be used in risky situations and moments where it is impossible to perform with the affected arm.

In his study, Dobkin (2004), recommends to make use throughout the day and during formal training six hours a day for two weeks. Furthermore, he establishes that it is more probable for the participants to improve if at home they practice blocks of 20 minute activities a couple of times a day. This same study explains that poor motor control is normally more limiting than muscular spasticity.

Another side, Siebers, Öberg & Skargren (2010) conducted a CIMT modified training on 20 participants with spastic hemiplegia, using as a form of evaluation the following assessments: MAS (Modified Ashworth Scale, from Bohannon & Smith, 1987)), AROM (Active Range of Movement), manual dynamometry, MAL (Motor Activity Log, from Uswatte & Taub, 2005)), Sollerman Hand Function Test, from Sollerman & Ejeskär (1995), and BBT (Box and Block Test, from Mathiowetz, Volland, Kashman & Weber, 1985). The results reveal significant reduction in spasticity (MAS test) right after the training and six months post training; significant improvements in AROM (elbow extension test, dorsal flexion test of the), manual strength (dynamometry test), and in the functionality of the arm (MAL test, Sollerman, BBT) after the two weeks of training and maintained after a six month follow-up. The authors affirm that training programs with greater frequency and repetitive concrete movement training reduces spasticity and improves functionality of the affected arm and hand. Therefore, they summarize that the CIMT increases motor skill and functionality of the affected member in daily activities.

In addition to the previously mentioned studies, Bonifer & Anderson (2003) conducted a case study of a person with severe hemiplegia in the superior right member, applied CIMT for three weeks. Significant improvements were obtained in the assessments: MAL, Fugl-Meyer, and GWMFT (Graded Wolf Motor Function Test). After six months, the improvements obtained from Fugl-Meyer and GWMFT, but not in the MAL test. There was no progress in the functional use of the affected member.

Rowe, Blanton & Wolf (2009) conducted a case study regarding the long-term effectiveness of the CIMT. The participants partook in the CIMT for two weeks and were evaluated before and after this application in addition measures took place four and five years post the CIMT application. The improvements in flexibility of the hand and arm obtained by the intervention five years post treatment. After five years of conducting the intervention, improvements in the use and abilities of the hand and leg were maintained.

Bang et al. (2015) investigate in their work the combination of mCIMT (modified Constraint-Induced Movement Therapy) with TR (Trunk Restraint) compared to research done exclusively with mCIMT. Each group conducted sessions of one hour per day, five days per week during four weeks. Measures were conducted with the ARAT (Action Research Arm Test), Fugl-Meyer, MBI y MAL. The mCIMT + TR group obtained two mayor improvements in all test than the mCIMT group.

Other authors who conduct studies with mCIMT are Page & Levine (2007). One of their studies sought to determine the efficiency of mCIMT protocol in participants with chronic cerebrovascular accidents presenting minimum mobility in the wrist and fingers. Four participants were selected and three sessions of 30 minutes per week for ten weeks were administered. The test used were ARAT, FM, and MAL. All showed significant improvements post intervention.

Finally, the study from Page, Levine & Khoury (2009) proved the usefulness of mental practice with mCIMT in comparison to an intervention with only mCIMT. Ten participants divided in two groups: mCIMT + mental practice or only mCIMT. Both groups participated in three sessions per week of mCIMT with tasks focused on functional use of the affected member. The mCIMT + mental practice group participated in an additional 30 minutes of mental practice in each session. All participants showed improvements in the ARAT and FM test, but the mCIMT + mental practice group showed greater significant differences post intervention.

Methods for functional re-adaptation: FES and NMES. The terms FES (Functional Electrical Stimulation) and NMES (NeuroMuscular Electrical Stimulation) make reference to the utilization of electrical stimulation in re-adaptation exercises for people with cerebral paralysis. In recent years, there has been an increase in the number of studies addressing this technique (Aoyagi & Tsubahara, 2004; Chae, Sheffler & Knutson, 2008; Embrey, Holtz, Alon, Brandsma & McCoy, 2010; Lin & Yan, 2011; Ng & Hui-Chan, 2009; Ring & Rosenthal, 2005; Yan, Hui-Chan & Li, 2005; among others), becoming popularly utilized in the re-adaptation environment in these types of persons due to technological innovations in therapeutic instruments, which allows us to adequately apply the electrical stimulation according to the desired benefits.

Chae et al. (2008) and Rajendra-Acharya et al. (2012) specify in their studies, the benefits of applying FES and NMES. On the other hand, Chae et al. (2008) explain that the application of NMES in rehabilitation purport therapeutic and functional benefits. In this way, FES makes reference to the utilization of NMES to achieve functional tasks such as ADL. These authors establish relevant terminology such as Motor Relearning, a term used to define the "recovery of motor skills previously learned but lost as a consequence of damage to the central nervous system". Furthermore, the authors affirm if the motor cortex has not been damaged it can play an important role in the motor relearning process. Other researchers, such as Rajendra-Acharya et al. (2012) affirm that FES is useful to purport more order, rhythm, and better control in physical activity for people with hemiplegia.

The work of Aoyagi & Tsubahara (2004) and Ring & Rosenthal (2005) make reference to the utilization of prosthetic for the application of FES. Aoyagi & Tsubahara (2004) analyzed the effectiveness of electrical stimulation in the reduction of the subluxation of the shoulder or to improve functionality of the wrist and finger extensors. They concluded articulating the need for further investigation to determine the effectiveness of this technique. From their part, Ring & Rosenthal (2005) conduct an intervention utilizing a neuro-prosthetics to conduct FES in the participant's rehabilitation. The findings reveal that when administering electrical activation to the participant by means of daily neuro-prosthetics as a supplement in addition to his regular rehabilitation improvements in the superior members are obtained.

With regards to the capacity to walk, diverse authors such as Embrey et al. (2010), Ng & Hui-Chan (2009), Sabut, Sikdar, Kumar & Mahadevappa (2011) and Yan et al. (2005) approach this topic from the electrostimulation perspective. Yan et al. (2005) examine the effectiveness of FES combined with conventional rehabilitation to improve motor recovery and walking capacity in persons who find themselves in the acute phase of the cerebrovascular accident. For this, 46 participants were divided into three groups: rehabilitation + FES, rehabilitation + electrostimulation placebo, and only rehabilitation. After three weeks of intervention, there were significant differences in spasticity, dorsal flexor muscular strength of the ankle, and the capacity to walk in participants of the rehabilitation + FES group, which were also significantly superior to the results of the other two groups. Embrey et al. (2010) investigated the utility of the FES when applying to the dorsal flexor musculature and position of the foot, dorsal and plantar flexion of the ankle when walking, thanks to electronic devices. The 28 participants were divided into two groups. The experimental group participated in the FES six to eight hours per day, every day, in addition to one hour per day of walking, six days per week, while the control group participate in walking only. Both groups had three months of intervention. The results showed significant improvements in both groups without significant differences among them. Other studies regarding re-adaptation is the work of Sabut et al. (2011), where the therapeutic effects of FES applied to the tibialis anterior, spasticity during plantar flexion, the strength applied in dorsal flexion, voluntary dorsal flexion, and the motor recovery of participants that have suffered a cerebrovascular accident. Fifty-one participants were divided into two groups: the experimental group receives 20-30 minutes of FES together with one hour per day, five days per week during 12 weeks of conventional rehabilitation, and the control group only received rehabilitation. Post-intervention assessments showed significant improvements in the experimental group compared to the control group. Furthermore, Ng & Hui-Chan (2009) studied the effects of the use of TENS (Transcutaneous Electrical Nerve Stimulation) to improve walking capacity. For this, four groups were established: TENS, TENS + exercise, placebo stimulation + exercise, and the control group. The TENS/placebo sessions lasted 60 minutes, the same time as the exercise sessions. The treatment was applied five days per week for two weeks. After the treatment, the TENS + exercise group presented significant improvements greater than the other three groups in walking velocity as measured by the Timed Up and Go test, while showing significantly greater results in the TENS and control group regarding the distance walked measured with the 6MWT.

In addition, authors like Hedman, Sullivan, Hilliard & Brown (2011), Karakus et al. (2013), Lin & Yan (2011), Mangold, Schuster, Keller, Zimmermann-Schlatter & Ettlin (2009), Mano et al. (2011) and Page et al. (2009) studied the FES and NMES application in the superior member. Mano et al. (2011) examined the effect of a NMES protocol on the articular range and the force of the hand in people with spastic hemiplegia after a stroke. NMES was applied on the extensors of the wrist and fingers for 30 minutes three days per week for eight weeks, complementing conventional rehabilitation. Significant improvements in the range of motion were obtained such as hand strength. From their investigation, Page et al. (2009) addressed the impact of FES on a participant with minimum mobility in the hands and fingers. The participant took part in task-specific training incorporating a robotic tool that provided FES, three hours per day, five days per week, for three weeks. After the intervention, there were significant improvements in assessments FM, AMAT, and ARAT, as well as the emersion of new abilities such as playing the piano. The work of Hedman et al. (2011) examines the effectiveness of a training program geared to the utilization of NMES. The intervention consisted of six weeks of practicing skills of daily life through the manipulation of objects assisted by NMES (NMES-assisted task practice), composed of three fifteen minute sessions per day. The tests conducted were FM, ARAT, and MAL. Post-intervention results demonstrated significant improvements in the ARAT and MAL test, and were maintained six weeks post-intervention, but the FM test, however, did not show significant improvements. Karakus et al. (2013) conducted a study to investigate the effects of FES on the function and spasticity of the wrist in victims of subacute/chronic phase of cerebrovascular accidents. For this, 28 participants were divided into two groups: FES or control. The FES group receives FES in the wrist and finger extensor muscles + standard rehabilitation, while the control group only receives rehabilitation. Measurements were conducted with the Motricity Index and Ashworth Scale, for passive flexor-extension resistance of the wrist with an isokinetic dynamometer. There were significant improvements with the Motricity Index in the FES group with regards to the control groups but not in the other results. The control group did not obtain significant improvements in any of the measures. In addition to these authors, Lin & Yan (2011) studied the long term efficacy of NMES in the motor recovery of the affected superior member. For this, 46 participants were divided into the NMES group or the control group. Both groups received a standard program of rehabilitation, while the NMES group received a standard program of rehabilitation, while the NMES group received an additional 30 min/day of NMES, five days/week during three weeks. Measures in the FM, MBI, and MAS test. The FM and MAS test showed significant improvements in both groups after three weeks of intervention and maintained one month post intervention. At three and six months post intervention, the results had discontinued but significantly higher in the NMES group. Finally, Mangold et al. (2009) tried to test for the effect of motor training combined with FES in the motor recovery of participants in the acute and subjugated phase of the cerebrovascular accident with severe or complete paralysis of the arm and/or hand. Twenty-three participants were divided into two groups: intervention and control. The control group participated in 12 sessions of conventional training. These were replaced by 12 sessions of training with FES for the intervention group. The intervention lasted four weeks. The test used were EBI (Extended Barthel Index), CMSA (Chedoke McMaster Stroke Assessment), and MAS. There were significant improvements in both groups according to the EBI and CMSA. The MAS test showed significant improvements in the intervention group. However, there were no significant differences between the two groups.

Another interesting investigation is Bakhtiary & Fatemy (2008) work, where the therapeutic effect of the electrostimulation in the spasticity of the flexor musculature of the ankle is analyzed. For this, 40 participants are divided into two groups: one group participate in 15 minutes of inhibition technique as explained by Bobath, while the other group's intervention involves nine minutes of a combination of electrostimulation and Bobath's techniques. The intervention involves 20 daily sessions. At the end of the intervention, there were significant improvements, greater in the group with the combined therapy of passive dorsal flexion of the ankle, in the strength of the dorsal flexion, and in the MAS test when compared to the results of the groups with Bobath's therapy. The culmination of the intervention revealed significant improvements greater in the group receiving combined therapy in the passive dorsiflexion of the ankle, the dorsiflexion strength, and the MAS test, when compared to the results of the group with Bobath's therapy.

The work of Chou et al. (2014), could be discussed as it proposes the FES as an instrument that improves walking mechanics and abnormal movement of superior members when walking. For this, and electronic device is incorporated to three participants who perform the FES while walking, controlling the steps and arm balance of the participants helping them maintain an adequate cadence. After four weeks of training, there were significant improvements with regards to the arm balance in the three participants.

Finally, the study of Ng & Hui-Chan (2010) is about the application in acupuncture of TES (Transcutaneous Electrical Stimulation) combined with TRT (Task-Related Training). In this case study five session per week for four weeks consisting of 60 minutes of TES and 60 minutes of TRT at home. The results obtained were a reduction in spasticity in the plantar flexor of the foot and improvements in the strength of the dorsal flexion and the plantar of the ankle. Improvements were also obtained in the walking speed, walking resistance, and functional mobility. These improvements were maintained at four weeks post treatment.

Methods for functional re-adaptation: Other techniques. This section will address studies which make reference to training methods and techniques, but doe to their characteristics these were not able to be included in the previous section of the manuscript but they are relevant to the topic at hand.

Lee & Lee (2014) conducted an intervention with 20 participants who had chronic hemiplegia. The intervention consisted of 30 minutes per day of SET (Sling Exercise Therapy) three days per week for four weeks. Significant improvements were obtained after four weeks of training in both the control group (participated in traditional exercise) and the experimental group (SET). Due to these results, the authors concluded that the SET method is just as effective to improve balance and core muscle strength as traditional exercise on a mat.

The work of Pattel, Lexell & Brown (2004) and of García-Soto, López de Munaín & Santibáñez (2013) talk about strength training. On one hand, Pattel et al. (2004) conduct a literature review regarding muscle weakness and strength training on people with hemiplegia. Their findings show that muscle weakness compromised in greater measure the functionality of movement than spasticity. These authors also detail a list of unresolved problems related to this type of training thus exposing possible lines of investigation to be explored. On the other hand, García-Soto et al. (2013) review the literature for the effects of resistance training, strength training, or combined, regarding the cognitive capacity of the participants in training. Among the principle conclusions the authors had was that physical activity is a useful strategy to improve cognitive function after a cerebrovascular accident. The need for more studies on this topic is further emphasized in addition to the need for more consistency in training protocols and in instruments of cognitive function evaluation.

Yan, Guo-chen, Jin-yu, Yun-guang & Liu-jiang (2013) conducted a study about the utilization of acupuncture in patients with hemiplegia due to a cerebrovascular accident. Thirty-six participants were included in the study and divided into two groups (control and intervention). Both groups received rehabilitation training. In addition, the intervention group received contralateral needling treatment while the control group received normal acupuncture in the same body points as the intervention groups. To measure the effects of the intervention, MAS and CSI (Clinical Spasticity Index) were used. The results showed significant differences in the improvements obtained in the intervention group when compared to the control group. These authors conclude that contralateral acupuncture complemented with rehabilitation training is an effective method to treat spastic hemiplegia.

Likewise, Chang & Lai (2015) add to the conventional rehabilitation a custom dynamic splint allowing rehabilitation exercises to be done at home. The rehabilitation consisted of five 30 minute sessions per week for three months. Voluntary contraction capacity, grip and finger strength, and participant satisfaction was measured. There were significant differences in the voluntary contraction capacity and finger and grip strength post at one and three months post intervention.

Pierce, Gallagher, Schaumburg, Gershkoff, Gaughan & Shutter (2003) designed and applied an individualized program consisting of one hour of occupational therapy and one hour of physical therapy to take place in the home for two to three weeks. In functional activities, a restrictive glove was placed on the non-affected hand. Measures were made by the WMFT, and there were significant improvements in 12 of the 17 subtests of this test.

Another interesting study that of Troncati, Paci, Myftari & Lombardi (2013), which looked at the long term effects of the ESWT (Extracorporeal ShockWave Therapy) application on muscle tone and motor function of the upper limb. Two sessions of ESWT were applied to 12 participants. Measures were conducted at three and six months post intervention with the MAS, FM, and PROM (Passive Range of Movement). In these three measures significant improvements were obtained in all three measures and maintain the improvement at three and six months follow up.

Additionally, the work of Kim, Kim & Gong (2011) approaches the analysis of the effects produced by core stabilizing exercises utilizing FNP (Facilitation Neuromuscular Proprioceptive) in muscle activation and in the FRT (Functional Reach Test). For this, 40 participants were divided into two groups: experimental, which conducted core stabilizing exercises using FNP; and the control group: which participated in a standard exercise program. Training sessions took place five times per week during six weeks. FRT and EMG (electromyography) were used to measure the effects of the intervention. The results showed the experimental group had significant improvements in the FRT and in muscle activation in the affected and non-affected side while the control group only had improvements in activation only in the non-affected side.

Hashidate, Shiomi & Sasamoto (2011) examined the effectiveness of a functional training program combined with low intensity on factors related to physical endurance, such as balance, leg strength, or motor function. Twenty-two participants took part in an intervention consisting of one to two sessions per week during six months of combined functional training. After six months of intervention there were significant improvements in muscle strength of the leg, postural balance, and walking.

Other authors that could be included in this section are Ada et al. (2006), who conduct a revision of the literature regarding strength training after a cerebrovascular accident. Their conclusion is that strength training increases strength and muscle activity without increasing spasticity. Their study concludes that this type of training should take part in rehabilitation plans for sufferers of cerebrovascular accidents.

Finally, Peurala, Tarkka, Pitkänen & Sivenius (2005) compare in their study, the effectiveness of a walk based intervention with a devise that supports body weight (gait trainer) in normal walking. For this 45 participants were divided into three groups: Gait trainer combined with FES (GT-FES); gait trainer without FES (GT); and regular walking. The three groups conducted 15 sessions (20 minutes each session) in three weeks in addition to 55 minutes per day of physiotherapy. The results demonstrate significant improvements in all three groups in the 10MWT (10-meter walk test), 6MWT, and MMAS (Modified Motor Assessment Scale), as well as spasticity and muscle strength of the inferior member. There were no significant differences among the groups and improvements were maintained throughout time.

Methods for functional re-adaptation: Studies using electronic or computer devices. Motoi et al. (2012) conducted a study regarding the utilization of a monitoring system to evaluate movement characteristics of the participants during rehabilitation, making it possible to quantitatively evaluate the efficacy of the rehabilitation of the participants.

The case study of Page et al. (2011) focused on a 53 year old participant with an affected arm. RTP was used three days per week for eight weeks, incorporating a neurobionics artefact to the intervention. Results demonstrated a reduction in the deficiency of the affected arm, increases in the ability to participate in activities included in the RTP and in the participant's satisfaction regarding his own endurance and improvements in health, ability to perform day-to-day activities, functionality, and participation. The results were obtained using the FM, COPM, and SIS test. The evaluations took place before and after the training program.

Other authors who utilized technological devises are Colomer et al. (2013), in their study of the efficacy of using the Armeo®Spring system in the rehabilitation of 23 participants with hemiparesis. Significant improvements were obtained after 36 one hour session addressing functionality [test FM, test MI (Motricity Index)] and in the execution of the activity [test Motor Assessment Scale, test MFT (Manual Function Test), test WMTF (Wolf Motor Function Test)]. There were no changes in muscle tone.

The work of Merkert, Butz, Nieczaj, Steinhagen-Thiessen & Eckardt (2011) examine the effects of a combination of training in a vibrating platform and balance training using Vibrosphere®. The control group received geriatric rehabilitation, while the experimental group received in addition 15 minutes of intervention with Vibrosphere®. The test of measure with the BBS (Berg Balance Scale), F-test, Barthel Index, TIN (Tinetti gait test), TUG (Timed Up & Go test) MMSE (Mini Mental State Examination), and EBI. There were significant differences in the functional measures for all the participants in both groups, but only significant differences among themselves in the Barthel Index.

Tong, Ng, Li & So (2006) carried out a case study regarding the utilization of an electronic devise for walk training simultaneously combined with FES for four weeks complementary to hospital rehabilitation. Measure were performed via the Barthel Index, BBS, MI, FACS (Functional Ambulation Categories Scale), and 5-MWT (5-Meters Walking Test). After four weeks of intervention, results showed significant improvements which were maintained six months post intervention.

Aditionally, Casale et al. (2014) utilize in their investigation a pneumatic vibrator applied to the center of the triceps brachii muscle of the affected member with a frequency of 100 Hz, to test its efficacy in functional re-adaptation. For this, 30 participants were divided into an experimental group (vibration + physiotherapy) and a control group (placebo vibration + physiotherapy). The intervention consisted of 60 minutes per day of physiotherapy, five days per week for two weeks. The results obtained showed a reduction in spasticity and greater control of it, as well as functionality in the affected member.

Also in this group, is a study by Miyara et al. (2014), in which the possibility of adapting the WBV (Whole Body Vibration) is tested. Specifically the study focused on legs affected by hemiplegia in addition to the anti-spastic effects and motor function improvement and walking capacity. Five minutes of WBV is applied to 25 subjects, with a frequency of 30 Hz and an amplitude of four to eight mm, in the sural triceps and hamstring muscles. Significant improvements were demonstrated in the MAS test, as well as in the AROM and PROM test, and in velocity and walking cadence.

Along the line of WBV, Pang, Lau & Yip (2013) analyze the effects of WBV regarding bone remodeling, leg muscle strength, motor function, and spasticity. For this, 82 participants are divided into experimental and control groups. The first received normal training together with WBV 15 minutes per day, three days per week for eight weeks; and the control group received the same intervention without WBV. The results did not yield evidence of significant improvements at the marker levels for bone remodeling nor in the motor function of the affected leg. However, muscle strength improved significantly in both groups with no difference amongst themselves, while spasticity had significant improvements in the experimental group but not in the control group.

Other interesting work is that of Cho, Park, Lee, Park & Kim (2015), where they conduct a robot-assisted gait training intervention and analyze its effects. For this, they divided 20 participants into two groups: one group received four weeks of robotic-assisted gait training intervention 30 minutes per day, three times per week, followed by four weeks of conventional physiotherapy, while the other group received the same intervention in a reverse order. The results showed that this type of training is efficient in improving balance and walking capacity in addition to improving core balance and motor capacity in order to perform ADL.

Lee et al. (2015), implemented a training combined with robotic assisted therapy with NMES to prove its effect on motor function and in the participant's quality of life. For this, 39 people were divided in two groups: RT (Robot Therapy) + NMES or RT + placebo stimulation. The intervention consisted of 90-100 minutes per day, five days per week, for four weeks. The test for measure were FM, MAS, WMFT, MAL, and SIS. Both groups demonstrated significant improvements in all measures, but the RT + NMES group had greater significant improvements in MAS, WMFT, and SIS.

Lastly, Barcala et al. (2013) conducted a study about balance training and visual feedback utilizing the Wii-Fit program. This study was conducted with 20 adults with hemiplegia divided into two groups. The experimental group utilized balance training with Wii-Fit, while the control group participated in conventional physical therapy. The intervention lasted five weeks with two sessions each week. The results showed no significant difference among the improvement in the experimental group and control group.

Conclusions

This study contributes to the body of knowledge in adding to the depth of knowledge regarding physical neuroadaptation in people that present hemiplegic cerebral paralysis by systematically organizing and putting into relevance the information obtained in previous studies. Findings from this information reveal that in most studies, the mere presence of physical activity during rehabilitation produces significant improvements in motor function; the application of electrostimulation encourages beneficial effects in the majority of re-adaptation cases in which it was used; and that methods which forces repetitive execution with the affected member, like the CIMT, favor functional improvements of the participants. Another aspect is the exposure of the principle limitations of neuroadaptation programs among which is the difficulty to carry out some of the methods studied albeit for functional aspects (CIMT, for example, limits for several hours a day the autonomy of the subjects when restricting the movement of the non-affected member) or due to economic aspects (those with a low level purchasing could be unthinkable when carrying out a functional re-adaptation employing methods such as WBV or electrostimulation, or further yet, a personalized rehabilitation). The different methods followed in different studies regarding how to carry out functional re-adaptation interventions with participants who present these characteristics, those who were successful demonstrated characteristics in common, these representing a relatively ample sample (minimum of 20 participants), conventional rehabilitation, assessments pre and post intervention and a follow-up in a predetermined time, and statistical comparisons among groups pre and post intervention. Nevertheless, there are still unanswered questions which require greater attention, and are related to absence of established protocols for physical activity exercise establish for people with this condition (number of recommended sets/ repetitions, number of exercise per day, etc.). Therefore, it is necessary to work on deeper research in this aspects in future investigations.

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