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EFFECTS OF FUNCTIONAL ELECTRICAL STIMULATION APPLIED TO THE WRIST AND FINGER MUSCLES OF HEMIPARETIC SUBJECTS: A SYSTEMATIC REVIEW OF THE LITERATURE

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ABSTRACT

Background: a systematization of the available evidence regarding the effects of electrical stimulation for hemiplegic patients following stroke is needed. Objective: to conduct a systematic review of the literature related to the effects of functional electrical stimulation for the wrist and finger muscles of adult hemiplegic patients. Method: a search for studies documenting the effects of electrical stimulation on neuromuscular, musculoskeletal and functional characteristics was carried out in Medline, Lilacs and PEDro databases between February and March 2006. Data were extracted in a standardized manner from each study, and methodological quality was assessed using the PEDro scale. Results: Eight randomized studies were reviewed. The scores on the methodological quality of revised studies were between 3/10 and 7/10 in the PEDro scale. Although the diversity of protocols, participants' characteristics and instrumentation prevented pooling of results, a synthesis in levels of evidence demonstrated strong evidence for positive effects of electrical stimulation on muscle strength, tonus, motor function and use of the upper limb in daily life. Moderate evidence was found for effects on dexterity and limited evidence for effects on motor coordination and independence in self-care activities. There was no evidence for gains in range of active wrist extension. Conclusion: Despite methodological limitations, randomized studies reported positive effects of electrical stimulation on wrist and fingers, suggesting that this therapy might be effective for promoting function of the affected upper limb of hemiplegic individuals.

Key words: Cerebrovascular accident; hemiplegia; wrist; functional electrical stimulation.

RESUMO

Efeitos da estimulação elétrica funcional nos músculos do punho e dedos em indivíduos hemiparéticos: uma revisão sistemática da literatura

Contextualização: Faz-se necessária sistematização das evidências disponíveis sobre os efeitos da estimulação elétrica em pacientes hemiplégicos após o acidente vascular cerebral. Objetivo: Realizar uma revisão sistemática da literatura referente aos efeitos da eletroestimulação funcional para os músculos do punho e dedos de pacientes hemiplégicos adultos. Métodos: Uma busca foi realizada nas bases de dados Medline, Lilacs e PEDro, no período de fevereiro a março de 2006, por trabalhos que documentassem os efeitos da intervenção nas características neuromusculares, musculoesqueléticas e funcionais. Dados foram extraídos de forma padronizada de cada estudo, e a qualidade metodológica foi avaliada utilizando-se a escala PEDro. Resultados: Oito estudos aleatorizados foram revisados. Em relação à avaliação da qualidade da evidência dos trabalhos, as pontuações variaram entre 3/10 e 7/10 na escala PEDro. Apesar da diversidade de protocolos, características de participantes e instrumentos utilizados terem impedido o agrupamento dos resultados, a síntese em níveis de evidência demonstrou que há forte evidência de efeitos positivos da eletroestimulação na força muscular, tônus, função motora e uso do membro na rotina diária. Há evidência moderada para efeitos na destreza e evidência limitada para efeitos na coordenação motora e independência em atividades de autocuidado. Não há evidências para ganhos na amplitude de extensão ativa de punho. Conclusão: Apesar de apresentarem limitações metodológicas, estudos aleatorizados relatam efeitos positivos do uso da eletroestimulação no punho e dedos, o que sugere que essa terapia seja eficaz para a promoção de função do membro superior afetado de indivíduos hemiplégicos.

Palavras-chave: Acidente vascular cerebral; hemiplegia; punho; estimulação elétrica funcional.

INTRODUCTION

A cerebrovascular accident (stroke) is a condition that can result in neurological damage and lead to disability or death[1]. Its manifestations frequently involve muscle weakness, spasticity and atypical motor patterns[2]. In most cases, a lesion occurs in the area irrigated by the middle cerebral artery, resulting in greater functional damage to the upper limbs[3]. The neuromusculoskeletal consequences of a stroke make it difficult or impossible to functionally use the upper limbs, which may hinder activities of daily life[4].

One of the techniques used in rehabilitation after a stroke is functional electrical stimulation (FES) that induces action potentials in the motor nerve, promoting the activation of motor units[5]. Effects such as strengthening of the stimulated muscle[6], facilitation of voluntary motor control[6] and spasticity reduction[6,7] have been reported after FES treatment.

Despite the possible benefits of the use of FES on hemiparetic patients' upper limbs, this resource has been limited to clinical practice, which may be due to the lack of knowledge of the effects of FES and of the adequate stimulation parameters[8]. Various clinical trials document the effects of FES on the wrist and fingers of hemiparetic patients[9-11]. Therefore, a systematic review of literature would aid intervention planning by providing a synthesis of the evidence on the effects of this therapeutic resource[12]. In light of the clinical issue related to FES effects on wrist and finger muscles of patients with hemiparesis due to stroke, the objective of this study was to conduct a systematic review of literature using sound selection and analysis of scientific articles that investigated the effects of this type of therapy.

METHODS

We researched the electronic databases Medline, Lilacs and PEDro in February and March 2006. The keywords used were: "electrical stimulation" or "electric stimulation" or "electrostimulation" and "wrist" or "hand" or "forearm" associated with "stroke", "hemiplegic", "hemiplegia", "cerebrovascular accident" and "CVA" (for more information on the efficacy of different search strategies, see Freitas et al.[13]). Searches were conducted without initial date or language restriction. Three researches selected the studies using the following inclusion criteria: 1) studies published in English, Spanish or Portuguese, 2) participants diagnosed with stroke, displaying hemiplegia or hemiparesis, 3) intervention defined as FES using surface electrodes, applied exclusively on the wrist and hand muscles, 4) intervention which was compatible with Brazilian clinical conditions, 5) presence of a control group, with or without randomization, 6) outcomes related to neuromuscular, neuromusculoskeletal and functional characteristics, 7) statistical analysis of results. Due to the fourth criterion, studies which made use of gloves or orthesis attached to stimulation devices were excluded. Disagreements between researchers regarding inclusion were resolved by consensus, taking into consideration the inclusion criteria.

The information in the studies was condensed in a standardized manner, based on the following topics: author(s), participants' characteristics, evaluated outcomes, methodology design, intervention characteristics (session frequency and duration, total treatment time and stimulation characteristics), statistical analysis used and effects found.

The studies were assessed as to their quality of methodology, using the PEDro scale[14]. This scale consists of 11 items, each item contributing with 1 point (except for item 1 which is not scored). The total score varies from 0 (zero) to 10 (ten).

Two authors assessed each article independently in relation to the presence or absence of the quality scale's indexes. Moderate reliability levels between assessors (ICC= 0.68; IC95%= 0.57-0.76) have been shown by the PEDro scale[15]. For the articles' final classification, differences of opinion were discussed until a consensus between authors was reached.

Because it was not possible to perform a meta-analysis due to the differences in relation to patients' characteristics, intervention protocols and measured outcomes or insufficient quantitative data (standard deviation means) in the reviewed studies, a result summary was used by means of an evidence level classification system. The classification, previously used in a systematic review in the field of neurological rehabilitation, included five scientific evidence categories according to the PEDro score and the results available in the studies[16] (Appendix 1).

RESULTS

Eighty-one studies were pre-selected by title content. After the abstracts were read, 25 articles were selected, of which 17 were excluded for failing to comply with the inclusion criteria. Therefore, 8 studies, all of them controlled and randomized, were included in the critical evaluation phase. Table 1 shows the data extracted from each article. Article scores in each item of the PEDro scale is shown in Table 2.

Participants' Characteristics

Half of the assessed studies[4,9-11] used a sample consisting of subjects diagnosed with acute stroke, with a post-cerebral lesion period of zero[9] to 7 weeks[4]. Four studies[7,17-19] had a sample with chronic stroke diagnosis, with post-lesion peri-

Table 1. Summary of information contained in the selected studies.

Authors	Subjects	Documented outcomes	Study design	Intervention	Statistical analyses	Observed effects (reported according to outcome number)
Chae et al.[9]	Clinical diagnosis: acute stroke (0 to 4 weeks) Severity: moderate to severe paresis (Fulg-Meyer score < 44). n=28, M=59.7, SD=13.0 years (TT: 14, Control: 14). 13 R, 15 L	1) Motor function (Fulg-Meyer) 2) Self-care (FIM)	Prospective, controlled, randomized; pre/ post-intervention assessments and follow-up (4th and 12th weeks).	TT: FES of common digitorum extensor and extensor carpi radialis, 1h a day, for 15 days (15 sessions). I=0 to 60mA, T=300μs, F= 25 to 50Hz, Ton and Toff : 10s, Rise and Decay =2s. Control: placebo FES with electrodes placed away from motor points	Independent t test and Chi-square	1) TT > Control after intervention (p=0.05) and at 4th follow-up week (p=0.05). Effects at 12th follow-up week. 2) Ns effect
Francisco et al.[11]	Clinical diagnosis: acute stroke (< 6 weeks) Severity: EMG signal> 5 μV in extensor carpi radialis and active extension strength < grade 3 (MMT). n=9 (TT: 4, M=60.3, Control: 5, M=69.6 years). 6 R, 3 L	1) Motor function (Fulg-Meyer) 2) Self-care (FIM)	Prospective, controlled, randomized; pre/ post-intervention assessments	TT: FES of extensor carpi radialis for 30 min, twice a day, 5 times a week during hospital stay + conventional therapy. I= 0 a 60mA , F= 20 a 100 Hz, Ton and Toff : 5s. Control: 30 min of wrist strength and ROM exercises, twice a day + conventional therapy	Mann-Whitney U, ANOVA	1) TT > Control (p=0.01). 2) TT > Control (p=0.02).
Powell et al.[10]	Clinical diagnosis: acute stroke (TT: M=23.9 days, Control: M=22.9 days) Severity: wrist extensors MMT ≤ grade 4 n=48 (TT: 25, M=69, SD=10.8; Control: 23, M=66.4, SD=12.6 years). 32 R, 38 L	1) Extensor isometric strength at 0º, 15º and 30º of wrist extension (device developed by the author) 2) Motor function (ARAT) 3) Active and passive wrist ROM (device developed by the author), wrist resting angle, muscle tonus (Ashworth scale), wrist discomfort at rest and at passive extension (6-Point Rating Scale and 10cm Visual Analog Scale), visual and spatial neglect (Star cancellation test), global disability and handicap (Rankin and Barthel), manual dexterity (9-Hole Peg Test), prehension strength (dynamometer).	Prospective, controlled, randomized; pre/ post-intervention assessments and follow-up (32nd week).	TT: FES of wrist and finger extensors for 30 min, 3 times a day, for 8 weeks + conventional therapy (Bobath and "Movement Science"). T=300μs, F=20 Hz, Ton and Toff: progression from 5/20s to 5/15s, 5/10s and 5/5s, Rise= 1s and Decay= 1,5s. Control: conventional therapy + physical therapists visits for 10 min, 3 times a week to discuss rehabilitation progress.	Independent t Test and Mann-Whitney U Test0	1) TT > Control at 0º after intervention (p=0.004) and at follow-up (p=0.014) and at 15º at follow up (p=0.009). Ns effect at 30º. 2) TT > Control only for grasp and grip after intervention (p=0.0013 e p=0.02). 3) Ns effect

Table 1. Continued.

Kimberley et al.[18]	Clinical diagnosis: stroke chronic (> 6 months, M=35.5, SD=14.5 months) Severity: active MCF and index finger extension and flexion ≥10^0. n=16, M=60.1, SD=14.5 years. (TT: 8, Control: 8). 8 R, 8 L	1) Manual dexterity (Box and Block Test and JTHFT) 2) Daily life function (MAL) 3) Finger active extension strength (dynamometer) 4) Finger movement precision control (functional magnetic resonance)	Prospective, controlled, randomized; pre/post-intervention assessments	TT: FES at finger and wrist extensors (EMG-triggered), 6hs/day, for 10 days, during 3 weeks, at home. T= 200µs, F= 50Hz, Ton =5s, Toff= 15s, Rise and Decay=1s Control: placebo FES with no current	Paired t Test, Wilcoxon Signed-Rank Test.	1) TT: ↑ Box and Block (p=0.039), ↑ performance in three JTHFT subtests (p≤0.043) after intervention. Control: ns effects. 2)TT: ↑ after intervention at both domains (p≤0.003). Control: ns effects. 3) ↑ for TT (0.006) and Control (0.01) after intervention 4) TT: ↑ only for ipsilateral GPoC (p=0.045). Control: ns effects.
Cauraugh[19]	Clinical diagnosis: chronic stroke (> 12 months) Severity: active wrist and fingers extension ≥ 10º from 90º of flexion. n=26, M=66.4; SD=9.7 years (TT: subgroup 1=10, subgroup 2=10, Control: 6). 11 R and 15 L	1) Manual dexterity (Box and Block test) 2) Activation characteristics: reaction time and sustained muscle contraction	Prospective, controlled, randomized; pre/post-intervention assessments	TT: 30 repetitions of FES at finger and wrist extensors with Ton=5s (subgroup 1) or 10s (subgroup 2) for session (90 min), twice a week+ bilateral extension movements T= 200 µs, F= 50 Hz and I=17 to 28 mA, Rise and Decay = 1 s. Control: bilateral extension movements	ANOVA	1) Subgroup 2: TT > Control (p value NA). Subgroup 1: ns effect 2) TT < Control for reaction time and TT > Control for sustained contraction (p value NA).
Cauraugh et al.[17]	Clinical diagnosis: chronic stroke (≥ 1 year) Severity: active wrist extension ≥ 20^0 from 90^0 of flexion n=11, M=61.64, SD=9.57 years. (TT: 7, Control: 4). 1 R, 10 L	1) Manual dexterity (Box and Block Test) 2) Motor function (Motor Assessment Scale and Fulg-Meyer). 3) Activation characteristics: reaction time and sustained muscle contraction	Prospective, controlled, randomized; pre/post-intervention assessments.	TT: 30 repetitions of FES at finger and wrist extensors (EMG-triggered) for session (60 min), 2 times a day, 3 times a week, for 2 weeks (12 sessions) + passive ROM + finger and wrist flexors stretch, F= 50 Hz, Rise and Decay =1s, Ton=5s and I=14 to 29mA. Control: same procedure but with placebo FES (with no current)	ANOVA	1) TT > Control (p<0.05). 2) Ns effect 3) Ns effect for reaction time. Sustained contraction: TT > Control (p<0.04).

Table 1. Continued.

Popovic et al.[4]	Clinical diagnosis: acute stroke (M=7, SD=2 weeks) Severity: HF Group: active wrist, MCP and IP extension, ≥ 20° LF Group: active wrist extension, thumb MCP and IP and at least 2 other fingers between 10° e 20°. n=28, M=59.9, SD=9.3 years. (TT: HF=8, LF=6 Control: HF=8, LF=6). 21 R, 7 L	1) ADL performance (UEFT) 2) Motor coordination (Drawing test) 3) Muscle Tonus (Ashworth scale) 4) Daily life function (RUE/MAL)	Prospective, controlled, randomized; pre/post-intervention assessments and follow-up (6^{th}, 13^{th} and 26^{th} weeks).	TT: 30 min of FES at finger flexors and extensors, thumb extensors and thenar muscles each session, 7 times a week, for 3 weeks, during functional activities such as brushing teeth, brushing hair and others + conventional therapy. F=50 Hz, T=200µs, I=20-50 mA. Control: 30 min of the same functional activities + conventional therapy	Mann-Whitney Rank Sum test and ANOVA	1) HF Group: TT > Control after intervention (p=0.04) and at 26^{a} follow-up week (p=0.01). LF Group: TT > Control after intervention (p=0.01) and at 26^{th} follow-up week (p=0.04). 2) HF Group: TT > Control after intervention (p=0.01) and at 6^{th} (0.01), 13^{th} (p=0.01) and 26^{th} (0.02) follow-up week. LF Group: TT > Control only at 13^{th} week (p=0.04) 3) HF Group: TT < Control at 26^{th} week (p=0.05). LF Group: ns effect 4) HF group: TT > Control at 26^{th} week (p=0.02). LF Group: ns effect
King[7]	Clinical diagnosis: chronic stroke Severity: NA n=21, M=67 years. (TT:11, Control:10)	1) Wrist flexor muscle tonus (resistance torque to passive movement)	Prospective, controlled, randomized; pre/post-intervention assessments	TT: 10 min of FES at wrist flexors (1 session). T= 259µs, F= 45Hz, Rise and Decay=3s; Ton and Toff=10s and I=15 to 20mA Control: 10 min of passive stretching	Independent t Test	1) TT < Control (p<0.001).

TT: treatment; M: mean; n: number of subjects; R: right; L: left; EMG Triggered: electrical stimulation triggered when a minimum voluntary activation level detected by electromyography is attained; MMT: manual muscle test; FIM: Functional Independence Measure; ARAT: Action Research Arm Test; FES: functional electrical stimulation; F: frequency; T: pulse width; I: amplitude; Ton: stimulation time; Toff: rest time; Rise: rise time; Decay: decay time; s: seconds; h: hours; min: minutes; ns: non-significant; HF Group: high-functioning group; LF Group: low-functioning group; MCP: metacarpophalangeal joints; IF: interphalangeal joints; JTHFT: Jebsen Taylor Hand Function Test; RUE/MAL: Reduced Upper Extremity Motor Activity Log; UEFT: Upper Extremity Function Test; ADL: daily life activities; NA: not available.

Table 2. PEDro Scale scores.

	Powel et al.[10]	Kimberley et al.[189]	Chae et al.[9]	Popovic et al.[4]	King[7]	Cauraugh et al.[19]	Cauraugh et al.[17]	Francisco et al.[11]
Eligibility criteria specified (item does not score)	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concealed allocation	Yes	No	No	No	No	No	No	No
Similar groups at baseline	Yes	Yes	Yes	Yes	No	No	No	No
Blinding of subjects	No	Yes	No	No	No	No	No	No
Blinding of therapists	No	No	No	No	No	No	No	No
Blinding of assessors	Yes	Yes	Yes	Yes	No	No	No	Yes
Measure of one key outcome obtained for 85% of subjects	Yes	Yes	Yes	No	Yes	No	Yes	No
Intention-to-treat analysis	No	No	No	No	No	No	No	No
Between-group comparisons of at least one key outcome	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Point and variability measures for at least one key outcome.	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Score	7	6	6	5	4	3	3	3

ods varying from 1[17] to 4 ½ years[18]. Sample size varied from 9[11] to 48[10] subjects divided between treatment and control groups. The participants' average age group was 59[9] to 69[10]. Individuals with right and left hemiparesis were included. The seriousness of the damage was described in different ways. However, in all studies, participants had to display at least 10º to 20º of active extension of the wrist and fingers.

Intervention program characteristics

Intervention duration varied from 1[7] to 120 sessions[10], with half of the articles having an intervention period of 10 to 15 sessions[4,15,18,19]. FES application frequency varied from 1[4,15] to 3[16] times a day, from 2[20] to 5[4,9-11] times a week. Session duration varied from 10 minutes[7] to 6 hours[18]. Current parameters varied, with frequency ranging from 20 to 100 Hz[11], amplitude from 14[17] to 60 mA[9] and pulse width from 200 to 300µs[9,10]. In most studies, FES was applied to extensor muscles[9-11,17-19]; in one study it was applied to wrist and finger flexors[7] and in another, to both muscle groups[4].

Effects of FES on neuromuscular and musculoskeletal characteristics

Muscle strength

Two randomized controlled trials (RCTs)[10,18] measured the wrist's extension isometric force and found significant gains in the group treated with FES. These gains were greater than those seen in one study's control group[10]. The results show strong evidence of the isometric strength gains for the wrist extensors after FES.

Muscle tonus

Tonus was assessed in three RCTs[4,7,10], two of which reported a significant tonus reduction. Popovic et al.[4] found a tonus reduction in comparison to the control group only in the high-functioning group (at least 20º of active wrist extension); in the low-functioning group (active extension between 10º and 20º), there was no significant reduction. King[7] found a reduction in flexor tonus after 10 minutes of FES in this muscle group compared to 10 minutes of stretching. According to the criteria adopted in this review, the results display strong evidence of tonus reduction after FES, which emphasizes that this effect can be limited to patients with active wrist extension greater than 20º prior to intervention.

Range of motion (ROM)

Active wrist extension range was assessed in one RCT[10] which did not find significant gains. There is no evidence of the effect of FES in this outcome.

Effects of FES on functional characteristics

Motor function

Of the four RCTs[9-11,17] that assessed motor function, three[9-11] showed positive effects after FES. Powell et al.[10] found significant gains in the *grip* and *grasp* subscores of the *Action Research Arm Test* when compared to a control group. Chae et al.[9] and Francisco et al.[11] observed significant motor gains for the intervention group compared to the control group by means of measurements taken with the *Fulg-Meyer* test (FM). There is strong evidence of motor gain after FES.

Manual dexterity

Four RCTs assessed manual dexterity after FES[10,17-19]. Powell et al.[10] did not find significant gains in the performance of the *9 Hole Peg test.* However, Cauraugh and Kim[19] assessed this outcome using the *Box and Block Test* after 4 sessions, obtaining significant gains compared to the control group only for the group that received FES with 10 seconds of electrical activation. There were no gains for the group that received FES with 5 seconds of electrical activation. Cauraugh et al.[17], using the same test, reported a gain of 129% in the FES group, significantly higher than the control group. Kimberley et al.[18] found a significant gain in the performance of the *Box and Block Test* and in subtests of the *Jebsen Taylor Hand Function Test* only for the FES group. According to the quality of the results of the reviewed articles, there is moderate evidence of the effects of FES on manual dexterity.

Motor coordination

There is limited evidence of the effects of FES on motor coordination. Only one RCT[4] measured the motor coordination of the affected limb using the *Drawing Test,* which assesses the ability to coordinate shoulder and elbow movement while the hand moves on a horizontal surface. There were superior gains in the high-functioning group, when compared to the control group, after FES and in assessments conducted at 3, 10 and 23 weeks after the end of intervention[4].

Use of upper limbs in daily routine

Both RCTs that measured this outcome found favorable results for FES. Kimberley et al.[18] used the *Motor Activity Log*, that assesses “how much” and “how well” subjects use the paretic arm in 30 activities of daily life. A significant improvement was found in test performance only for the FES group. Popovic et al.[4] used the *Reduced Upper Extremity Motor Activity Log* test and found significant gains in the high-functioning group compared to the control group. These authors also used the *Upper Extremity Function Test* and found a significant difference between subjects from the high and low-functioning groups that received FES treatment and their respective control groups. There is strong evidence of functional gains in daily routine after FES, with intervention apparently having greater potential for patients with at least 20º of active wrist extension prior to intervention.

Independence in self-care activities

Two RCTs[9,11] assessed this outcome using self-care items of the *Functional Independence Measure*. There were conflicting results, with significant gains found only in a low-quality study[11]. Therefore, there is insufficient evidence of the effects of FES on independence.

Other outcomes

Powell et al.[10] analyzed the effects of FES on local wrist discomfort at rest and in passive extension, global incapacities and disabilities and visuospatial negligence. The authors did not find significant difference for these measurements when comparing the treatment and control groups. There is no evidence of the effects of FES on these outcomes.

Adverse effects

Outcomes related to adverse effects were not measured directly in seven of the eight studies[4,7,9,11,17-19]. Francisco et al.[11] and Chae et al.[9] only suggested that some participant drop out might be linked to the pain and discomfort caused by FES. Therefore, it was not possible to classify this outcome in evidence levels.

DISCUSSION

All analyzed studies used experimental methodological design, which compares two or more treatments, having one control or reference group[20]. This type of study provides structure to assess the cause and effect relationship in a group of variables, therefore making evident the causality of possible changes observed in the participants[20]. All studies also used random subject allocation and were classified as randomized controlled trials. Randomization does not allow results to be influenced by selection bias, which may predispose a group to being more sensitive to the effects of intervention[20].

Although five studies[4,9-11,18] scored in blinding its assessors, only one[18] blinded its subjects, and three[7,17,19] did not have any type of blinding. Blinding is a relevant aspect because the investigators’ expectation regarding assessed outcomes and the participants’ knowledge of their treatment may influence measurement results.

Of the assessed studies, only those by Chae et al.[9] and Kimberley et al.[18] were experimental, randomized and double-blinded studies, which are considered the gold standard for the assessment of intervention efficacy and result consistency[20]. Chae et al.[9] found significant gains in motor function (Fulg-Meyer) in the post-treatment phase and in the fourth week of follow-up; Kimberley et al.[18] reported gains in dexterity and functionality in daily life in the FES group compared to the control group.

Due to the diversity of protocols, participant characteristics and devices used, it was not possible to group studies in order to analyze results quantitatively. However, the classification by evidence levels indicates that there is strong evidence of positive effects of FES on muscle strength, tonus, motor function and limb use in daily routine. There is moderate evidence of dexterity effects and limited evidence of effects on motor coordination and independence in self-care activities. There is no evidence of gains in active range of motion. Future studies should investigate the influence of changes in parameters such as application time and frequency, current intensity and pulse width on gains obtained with intervention.

CONCLUSION

Randomized studies offered evidence of the positive effects of FES on wrist and finger muscles of hemiplegic patients. Future investigations may shed light on some inconsistencies observed in study results, possibly due to differences in the types of protocols, patient characteristics and devices used. The results of this systematic review study synthesize evidence of the effects of FES that may contribute to clinical actions of professionals who work with this clientele and use FES, favoring evidence-based practice.

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APPENDIX 1

Level of evidence synthesis criteria

Strong evidence

Provided by statistically significant findings in outcome measures

- at least two high-quality Randomized Controlled Trials (RCTs), with PEDro scores of at least 4 points*.

Moderate evidence

Provided by statistically significant findings in outcome measures in:

- at least one high-quality RCT **and**
- at least one low-quality RCT (5/3 points on PEDro) or one high quality Controlled Clinical Trial (CCT)*.

Limited evidence

Provided by statistically significant findings in outcome measures in:

- at least one high-quality RCT **or**
- at least two high-quality CCTs* (in the absence of high-quality RCTs).

Indicative findings

Provided by statistically significant findings in outcome measures in:

- one high-quality CCT or low-quality RCTs* (in the absence of high-quality RCTs), **or**
- two studies of a non-experimental nature with sufficient quality (in absence of RCTs and CCTs).

Insufficient or no evidence

- In the event that results of eligible studies do not meet the criteria for one of the above stated levels of evidence, **or**
- in the event of conflicting (statistically significant positive and statistically significant negative) results among RCTs and CCTs, **or**
- in the event of no eligible studies.

*If the number of studies that show evidence is 50% of the total number of studies found within the same category of methodological quality and study design (RCT, CCT or non-experimental studies), no evidence will be classified.