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ELECTROMYOGRAPHIC BIOFEEDBACK EFFICACY IN MOTOR FUNCTION RECOVERY AFTER PERIPHERAL NERVE INJURY: AN INTEGRATIVE REVIEW OF THE LITERATURE

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Dissertação apresentada ao Programa de Pós-graduação em Medicina e Saúde, da Faculdade de Medicina da Bahia, Universidade Federal da Bahia, como requisito para a obtenção do grau de Mestre em Medicina e Saúde.

Orientador: Profº. Dr Abrahão Fontes Baptista

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LISTAS DE ABREVIATURAS E SIGLAS

BFB	Biofeedback eletromiográfico
BP	Bell's palsy
BTX-A	Botulin toxin A
CBI	Cognitive Behavioral Intervention
CG	Control Group
CTS	Carpal Tunnel Syndrome
EBF	Electromyographic biofeedback
ET	Exercise therapy
FP	Facial paralysis
LNP	Lesão nervosa periférica
MF	Mirror feedback
PICO	Patient, Intervention, Comparison, Outcomes
PNI	Peripheral nerve Injury
RCT	Randomized clinical trial

RESUMO

Introdução: O biofeedback eletromiográfico (BFB) tem sido aplicado para tratar diferentes tipos de lesão nervosa periférica (LNP). No entanto, apesar do uso clínico difundido possui evidência controversa.

Objetivo: Investigar a eficácia e efetividade do BFB na recuperação da função motora de indivíduos com LNP. O objetivo secundário foi identificar o racional teórico e estratégias utilizadas nas intervenções com BFB, e a qualidade das descrições técnicas dos procedimentos com BFB.

Métodos: Foi realizada uma revisão integrativa da literature entre Outubro de 2013 e Setembro de 2016, nas bases de dados da PUBMED, ISI e COCHRANE. Foram incluídos artigos originais que utilizassem o BFB no tratamento de indivíduos com LNP de qualquer etiologia, publicados nas línguas inglesa, portuguesa, francesa e espanhola, após 1990. Os critérios de exclusão foram descrição incompleta do tratamento com BFB, tratamento associado ao BFB que pudesse limitar a conclusão dos efeitos do BFB nos desfechos, inclusão de indivíduos que não tivessem lesão nervosa periférica e estudos de caso. A escala PEDro foi utilizada para avaliar a qualidade dos ensaios clínicos incluídos.

Resultados: Setenta e um artigos em potencial foram selecionados para leitura completa, porém, somente nove estavam dentro dos critérios de inclusão. Os indivíduos dos artigos incluídos possuiam lesões diversas,como, paralisia facial, inflamação ciática aguda, sindrome do túnel do carpo. A média da qualidade dos ensaios clínicos foi de 5, correspondendo a qualidade metodológica baixa.

Limitações: Devido ao pequeno número de artigos incluídos, baixa qualidade metodológica e heterogeneidade das intervenções, desfechos e população.

Conclusão: As evidências acerca da eficácia e efeitivdade do BFB na recuperação da função motora após LNP é limitada.

Palavras Chaves: lesão nervosa periférica; biofeedback; função motora; reabilitação

ABSTRACT

Background: Electromyographic biofeedback (EBF) has been applied to treat different types of peripheral nerve injuries (PNI). However, despite the clinical practice widespread use its evidence is controversial.

Objective: Investigate electromyographic biofeedback effectiveness and efficacy for the recovery of motor function of peripheral nerve injury subjects. Secondary objective was to identify the conceptual framework and strategies of EBF intervention, and the quality of technical description of EBF procedures.

Methods: To conduct this integrative review a systematic search of the literature was performed between October 2013 and September 2016, in PUBMED, ISI and COCHRANE databases for EBF original studies in PNI patients of any etiology, in English, Portuguese, Spanish or French, published after 1990. Exclusion criteria were poor description of EBF treatment, associated treatment that could impair EBF effect conclusions on results, and inclusion of non-PNI individuals, case studies design. The PEDro scale was used to evaluate study quality of randomized clinical trials (RCTs) included.

Results: Seventy-one potential articles were enrolled to full reading, although only nine matched the inclusion criteria. PNI included facial paralysis, acute sciatic inflammation, carpal tunnel syndrome. The average quality score of the included RCTs was 5, corresponding to low methodological quality.

Limitations: Due to the small number of included articles, studies low quality and heterogeneity of interventions, outcomes and population.

Conclusion: There is limited evidence of EBF effectiveness and efficacy for motor function recovery in PNI patients.

Key-words: Peripheral nerve injury; biofeedback; motor function; rehabilitation;

1. INTRODUÇÃO

Diversas afecções estão englobadas na definição de lesão nervosa periférica (LNP), podendo ter causas mecânicas, químicas, infecciosas e autoimunes. Diferentes manifestações clínicas podem ocorrer decorrentes de alterações a nível periférico e central que afetam aspectos sensoriais, motores ou autonômicos do indivíduo. Também são diversos os tratamentos de reabilitação utilizados, por exemplo, diferentes modalidades de eletroterapia, fototerapia acupuntura e o biofeedback eletromiográfico (BFB).

O BFB pode ser considerado como uma ferramenta que facilita o aprendizado motor. Um dispositivo fornece pistas sensoriais extrínsecas aos indivíduos referentes a informações sobre o resultado e a qualidade de sua atividade mioelétrica frente a execução de um objetivo. Através da manipulação da atividade muscular ocorre o aprendizado motor e a melhora da função.

A vantagem do tratamento com o BFB, em relação a outras terapias é a alta sensibilidade em detectar contração muscular. Esta característica é muito importante no tratamento de sujeitos com lesão nervosa periférica, pois a atividade muscular pode passar despercebida pelos próprios indivíduos e terapeutas. O feedback imediato facilita o reaprendizado de músculos reinervados, aumentando a atividade destes e diminuindo contrações aberrantes, como as sincinesias. Por isso, este tipo de terapia tem potencial para promover o movimento muscular voluntário de forma seletiva.

BFB tem sido indicado no tratamento de uma série de LNP, como as lesões do plexo braquial, do nervo facial, na síndrome de Guillain-Barré, síndrome do túnel do carpo e lesões traumáticas dos nervos apendiculares. Apesar do seu uso difundido na prática clínica, são poucos os ensaios clínicos que investigam os efeitos das intervenções com BFB na LNP.

No sentido de sumarizar as evidências disponíveis sobre o uso do BFB na recuperação da função motora de LNP, e ajudar clínicos na tomada de decisão, realizamos uma revisão integrativa acerca da efetividade do BFB de sujeitos com lesão nervosa periférica.

2. OBJETIVO

Investigar a eficácia e efetividade do BFB na recuperação da função motora de indivíduos que sofreram LNP.

3. RESULTADOS

3.1 ARTIGO DE REVISÃO

Electromyographic biofeedback effectiveness in motor function recovery after peripheral nerve injury: an integrative review of the literature

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Responder

Re: "Electromyographic biofeedback efficacy in motor function recovery after peripheral nerve injury: an integrative review of the literature"
Full author list: Rafael Jardim Duarte-Moreira, Msc; Kamyle Villa-Flor Castro, B Physio; Cleber Luz Santos, Msc; José Vicente Pereira Martins, Msc; Katia Nunes Sá, PhD; Abrahao Fontes Baptista, PhD

Dear Msc Duarte-Moreira,

We have received the submission entitled: "Electromyographic biofeedback efficacy in motor function recovery after peripheral nerve injury: an integrative review of the literature" for possible publication in Applied Psychophysiology and Biofeedback, and you are listed as one of the co-authors.

The manuscript has been submitted to the journal by Dr. Prof. Abrahao Fontes Baptista who will be able to track the status of the paper through his/her login.
If you have any objections, please contact the editorial office as soon as possible. If we do not hear back from you, we will assume you agree with your co-authorship.

Thank you very much.

With kind regards,

Springer Journals Editorial Office
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Introduction

Injury to peripheral nerves (PNI) may have differing causes, such as mechanical, infectious and chemical stress, and autoimmune diseases(Ferreira 2006). PNI can be insidious or persistent and, regarding duration, lesions may be progressive or not(Fox and Mackinnon 2012). Motor dysfunction is the main finding (Dobson et al. 2014; Vaz et al. 2015). PNI may result in muscle atrophy, decreased strength or paralysis(Smania et al. 2012). Besides that, sensory alterations such as perception of light touch and pin pricks, joint position sense, vibration, autonomic dysfunction and pain(Smania et al. 2012) may impair even more movement performance (Oud et al. 2007).

Neuroplastic changes occur during nerve damage and reinnervation process, or with the continuation of noxious stimuli, as seen in carpal tunnel syndrome (CTS)(Ginanneschi et al. 2012). Changes that take place in cortical map can hamper the individual functional recovery(Novak 2008). Several rehabilitation strategies have been applied to prevent or mitigate these changes, and to prevent functional loss, or increase the subjects' residual abilities. These interventions include different electrotherapy modalities(Pieber et al. 2010; Stein et al. 2013), exercise(Toth et al. 2014), acupuncture(De Albornoz et al. 2011) and sensory re-education(Oud et al. 2007). However, there is limited evidence for these procedures, probably due to the diversity of lesions and therapeutic approaches (Cardoso et al. 2008; Oud et al. 2007; Teixeira et al. 2008).

One of the most challenging aspects in PNI rehabilitation is that decreased or absent sensory and movement perception becomes a major barrier to therapeutic exercises and functional activities(Duff 2005). This makes the affected region, which often still has a functional potential, to be abandoned during daily life activities. External cues can help the individual to develop functional abilities that are not fully disabled, but remain imperceptible(Novak 2004; Pourmomeny et al. 2014).

Electromyography biofeedback (EBF) consists of using a device that displays for the individual his/her own muscle electrical activity through audiovisual cues, helping to accomplish functional goals otherwise impossible(Criswell 2011; Kasman et al. 1998). This method has the advantage of high sensitivity to identify muscle contractions and provides immediate real time feedback(Kasman et al. 1998; Pourmomeny et al. 2014). It is a motor learning tool(Kasman et al. 1998) that facilitates the acquisition of new tasks, and contributes to muscle strengthening and recruitment while reinnervation takes over(Novak 2004, 2008). Furthermore, it allows the comparison of the external cues to the subject's own perceptions, what will favor sensory perceptual system adaptation to the actual condition(Kasman et al. 1998; Lauber and Keller 2012).

EBF has been used to treat various PNI(Ferreira 2006) such as Guillain-Barré syndrome(Ince and Brenes Jette 1987), fibular nerve lesion(Kirdi et al. 1998), brachial plexus injury(Chung et al. 2012; Novak

2008), and more commonly, facial paralysis (FP)(Novak 2004). Despite its clinical widespread use, there is controversial evidence about PNI treatment effects. In order to summarize the available evidence on the PNI treatment with EBF, an integrative review was performed to investigate the electromyographic biofeedback effectiveness and efficacy to help motor function recovery after PNI. As a secondary objective, we aimed to identify the conceptual framework and strategies of EBF intervention, and the quality of technical description of EBF procedures, as it may be a marking challenge for study homogeneity and clinical evidence development.

Methods

This integrative literature review includes a systematic review of the literature performed between October 2013 and September 2016. Inclusion criteria were electromyographic biofeedback original studies for PNI treatment of any etiology, in English, Portuguese, Spanish or French, published after 1990. This specific time point was defined as technology before this period was quite different from actual. Case studies were not included because of its weak evidence level. Exclusion criteria were poor description of EBF treatment, associated treatment that could impair EBF effect conclusions on results, and inclusion of non-PNI individuals.

The search for articles was made in PUBMED, ISI and Cochrane databases. In the latter, review references were screened. The search strategy was based on the PICO (patient, intervention, comparison, outcome) structure. The population keywords were: neuromuscular disease, peripheral nerve injury, peripheral nerve lesion, nerve lesion, nerve injury, nerve crush, neurotization, nerve transfer, neurorraphy, Bell palsy, Bell idiopathic facial nerve, median nerve, ulnar nerve, radial nerve, femoral nerve, peroneal nerve, sciatic nerve, isquiatic nerve, neuropathy, brachial plexus lesion and neuropathies. Intervention keywords were: Biofeedback, EMG biofeedback, electromyographic biofeedback, muscle biofeedback, EMG feedback, electromyographic feedback and myo feedback. Comparison keywords were not stablished because any kind of treatment was included in the study. Outcomes were also not defined, but all motor outcomes were considered after the reading of included studies. Finally, the unwanted population and intervention keywords were: laboratory animals’ study, rat, mouse, mice, rabbit, stroke and neurofeedback. Boolean descriptors "AND", "OR" and "NOT" were used. The search strategy is presented in appendix 1.

Publications search and selection were performed independently by two researchers in three stages, firstly titles, then abstracts, and finally full text appreciation. After each stage, both researchers were convened to decide on the articles next step inclusion. When agreement regarding the inclusion of an article was not reached, a third researcher was available and decided about the article inclusion or exclusion.

Data on year of publication, study design, sample size, type, severity and stage of disease, treatment characteristics, motor function outcomes and results were extracted. Motor function outcomes were described as: strength, active range of motion, functional tests and scales' indexes.

Only RCTs quality were evaluated through PEDro scale(Macedo et al. 2010; Maher et al. 2003). This scale comprises 11 items that assess the studies' internal and external validity. Each item accounts as one point in the PEDro score, except for the first item, that discusses participants eligibility(Maher et al. 2003). A score > 6 is equivalent to a moderate to high quality study. Two researchers carried out quality evaluation independently. When necessary a third investigator was contacted to resolve disagreements.

Results

From PubMed and ISI database and references resulting from the single article found in the COCHRANE database, 942 studies were found, but we identified only 71 potential articles for inclusion. After duplicate removal and abstract reading we selected 24 articles for thorough analysis. Between the excluded studies, one was in German language (Volk et al. 2014), three were reviews (Novak 2004; Kinlaw 2005; Vanswearingen 2008), two included a population or control group not composed with PNI subjects(Chiu et al. 2013; Peirce et al. 2013; Stafford et al. 2007), three did not clearly describe EBF treatment(Adigüzel et al. 2016; Terzis and Karypidis 2012a, 2012b), two combined EBF with other technique that could impair judgment about results(Lee et al. 1996; Wong et al. 1997), one did not use EBF as treatment(Segal et al. 1995), and one did not state with clarity the type of feedback used(Shiau et al. 1995). Although various attempts were made, it was not possible to have access to two studies(Dubravica M, MusuraM, Nesek-Madaric V and D. 1996; Manca M, Contenti E, Mura G, Basaglia N 1997).

At the final analysis nine articles were included(Brach et al. 1997; Cronin and Steenerson 2003; Dalla Toffola et al. 2005; Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012; Hasenbring et al. 1999; Pourmomeny et al. 2014, 2015; Ross et al. 1991; Thomas et al. 1993), four of them were RCTs(Hasenbring et al. 1999; Pourmomeny et al. 2014, 2015; Ross et al. 1991). The included studies involved a total of 374 PNI subjects and of these, 173 underwent intervention with EBF. Only two of them treated PNI other than FP(Hasenbring et al. 1999; Thomas et al. 1993). Studies characteristics, sociodemographic, and clinical data, intervention frequency and duration, follow-up time and primary assessment tools and results are disposed at table 1.

Facial Paralysis

The majority of studies found in this review included FP subjects, four of them included participants with diverse etiologies of the disease(Brach et al. 1997; Cronin and Steenerson 2003; Pourmomeny et al. 2014; Ross et al. 1991), while the others only Bell's Palsy (BP) individuals(Dalla Toffola et al. 2005;

Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012; Pourmomeny et al. 2015). Although the variety of FP etiologies could have interfered with homogeneity of the results, no individual study showed between group differences at baseline.

EBF was compared with different techniques as mirror feedback (MF)(Ross, Nedzelski, and McLean 1991; Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012), exercise therapy (ET)(Dalla Toffola et al. 2005), EBF associated with botulin toxin A (BTX-A)(Pourmomeny et al. 2015) and with no treatment(Cronin and Steenerson 2003; Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012; Ross et al. 1991). One study used routine physiotherapy in the control group, but did not clearly state the interventions(Pourmomeny et al. 2014). Only one article did not involve a controlled design(Brach et al. 1997).

EBF and MF treatments seems to have the same influence on peripheral nerve recovery. Dalla Toffola et al. (2012) showed that EBF and MF were similar, and also did not differ from no treatment (Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012). However, both active groups were composed by participants with moderate to server axonotmesis, while the control group was composed by participants with neuropraxia. The average days to recover were similar between the treated groups (54 days for EBF, and 52 for MF).

EBF was also added to BTX-A or saline injection to treat synkinesis in patients after six months of lesion. This study also did not find difference between both groups, suggesting that EBF was superior to the injection interventions. (Pourmomeny et al. 2015)

EBF strategies were similar in all studies. Electrodes were placed in hypoactive and weak muscles with aim to help the increase of electromyographic activity. If synkinesis was present, another electrode was positioned over hyperactive muscles to guide its voluntary inhibition. Cronin et al. 2003(Cronin and Steenerson 2003) also placed electrodes in the healthy side of the face and asked patients to make similar muscle contractions in both sides based on electromyographic activity, a kind of strategy named motor copy(Criswell 2011). Other studies(Dalla Toffola et al. 2005; Dalla Toffola and Tinelli, C. Lozza, A. Bejor, M. Pavese 2012) added functional movements and words pronunciation to EBF, while avoiding synkinesis. However, treatment dosage marked varied between studies, making it difficult to compare strategies. Some authors preferred to personalize the dosage, but none of them described the criteria to determine frequency or interruption of the treatment.

Other pathologies

Only two studies included pathologies other than FP. Thomas published a non-randomized controlled study(Thomas et al. 1993) showing the effect of EBF for carpal tunnel syndrome in 10 working women of a hardware factory assembly line. The five participants of the experimental group used EBF in order to modify their behavior. Every time forearm muscles were excessively activated or an inadequate hand posture was made, an auditory signal was activated. The control group did not undergo any intervention. The outcome measure was grip strength and there was no significant difference between groups at the end of the intervention.

Hasenbring(Hasenbring et al. 1999) studied acute sciatica subjects, a different type of peripheral nerve lesion, as the major symptoms were pain and not functional impairment. The trial consisted of five groups, three of them subjected to conventional medical treatment and of these, two included individuals with high psychosocial risk for chronicity. The other two groups were also composed by individuals with high psychosocial risk, but received different behavioral treatments. One underwent cognitive behavioral intervention (CBI) and the other EBF aimed to assist spinal muscles relaxation. The primary motor outcome was the inability to perform daily living activities (Immobility in everyday life) and physical disability related to pain. Although, EBF group had improved at all evaluations, CBI group presented better results.

Methodological aspects

General description of equipment characteristics, signal processing, electrode placement, cues and feedback modality were poor or nonexistent in almost all studies. Only two studies described signal processing, one used electromyographic integrated signal(Cronin and Steenerson 2003), and signal was displayed as graphs at another one(Brach et al. 1997).

With exception to one paper (Brach et al. 1997), the others did not specify the target muscles nor the electrode placement protocol. Generic descriptions included forearm, hand, face and spine muscles. Two studies did not state the type of cues used(Pourmomeny et al. 2014; Ross et al. 1991). No studies have explicitly indicated the feedback modality. None of them evaluated the adverse effects, treatment satisfaction and adherence.

Quality appraisal of the included studies

The included studies showed and average score of 5 points (4-6 points) according to PEDro scale. Three trials had already been scored by PEDro team, with scores of 6(Ross et al. 1991), 5(Pourmomeny et al. 2014) and 4(Hasenbring et al. 1999) points, these scores were retained. We rated the other RCT, which received 5 points(Pourmomeny et al. 2015). According to the PEDro cutoff point, which is to have a score >6(Maher et al. 2003), only one study could be ranked as moderate to high quality(Ross et al. 1991). Studies' quality characteristics according to PEDro scale are shown in table 2.

Discussion

This study showed that, in general, biofeedback studies aiming the improvement of motor outcomes after PNI show low methodological quality, and their results should be viewed with caution. The main methodological limitations of the included studies were inadequate or lack of randomization, improper allocation of the participants, inadequate blinding, low study power, lack of an adequate control group and heterogeneity in the degree of lesion and intervention procedures. Technical aspects of equipment and many treatment details were missing in all studies. These methodological flaws hamper internal validity of EBF studies (Verhagen et al. 1998). Failure to address these items can have overestimated intervention effects, and generated inadequate results(Kunz and Oxman 1998; Moher et al. 1998; Schulz et al. 1995)

In general, EBF was similar to other biofeedback interventions, such as MF. Probably they act via the same mechanisms, helping to prevent massive muscle contractions and to increase selective control. In the peripheral environment, the selective, non-massive facial muscle contractions provide a better targeting for the neural growing of neuronal sprouts(Azuma et al. 2012). biofeedback training would help the patient to a better discrimination of individual muscle contractions, which may lead to a better quality of muscle reinnervation, although this remains to be demonstrated. Also, biofeedback neuromuscular reeducation may influence muscles' cortical representation, helping the reestablishment of a normal configuration (Azuma et al. 2012; Novak 2004).

Almost all studies included in this review involved participants with chronic facial palsy. Strategies to these individuals have been focusing on inhibition or prevention of synkinesis. Treatment of FP should start as soon as possible, that means, when the first action potential of affected muscle is recorded(Pourmomeny et al. 2014). It is stated that prevention is more effective than treating the already established synkinesia(Azuma et al. 2012). In future studies, interventions in the acute phase should be emphasized. EBF offers the possibility to identify even minimum activity of weak/hypoactive muscles, and also to progress exercises to functional movements and more complex tasks while avoiding synkinesis.

EBF may help to control excessive or insufficient muscle use during daily tasks. The basic assumption of Thomas et al. (1993) that excessive force output from forearm muscles and weird hand postures contribute to carpal tunnel syndrome has some evidence (Harris-Adamson et al. 2015; Shen and Li 2013; You et al. 2014). However, this study presented important limitations, as there was no behavioral assessment of the workers, before or after treatment, which made it impossible to know if EBF was effective in helping to modify wrong gestures. Other problem is that women who participated were trained at the beginning and taught to place the electrodes themselves, with no supervision during the whole treatment. This could explain the null results since diverse studies have shown the therapist presence importance.

The same educational use of EBF was used at Hasenbring et al. 1999 study(Hasenbring et al. 1999). Individuals with back pain were taught to identify back muscle hyperactivity during stressful situations, and to decrease EMG activity. Results showed improvement in motor outcomes, such as physical dysfunction and daily life activities. However, CBI had better results than EBF. As the participants in the CBI group received more sessions than those who were submitted to EBF, it is impossible to know if confirm the superiority of the first intervention. Other possible explanation is that the biomechanical rationale was not used. In acute and chronic low back pain individuals there is modification in the cortical maps of trunk muscles(Massé-Alarie et al. 2016; H. Tsao et al. 2008), represented by an overlapping motor cortical areas(Henry Tsao, Lieven Danneels 2012), and change in trunk muscle excitability (Massé-Alarie et al. 2016; H. Tsao et al. 2008, 2011). Interesting though, skilled training, with attention, could induce cortical map reorganization and was associated with motor coordination recovery in recurrent low back pain individuals(Henry Tsao et al. 2010). It is possible that individuals benefit more associating psychophysiology and biomechanical approaches early at the low back pain acute phase.

Studies with peripheral nerve lesions often present their specific difficulties, since it is very hard to standardize the degree of lesion itself. The progression of regeneration depends on many individual factors and is frequently very long, which limits the use of control groups. All those factors put peripheral nerve lesion studies in a unique condition, which very rarely may be compared to clinical trials in other areas. Other study designs should be encouraged; a good example is a single subject design with multiple baseline across subjects and with probe tests, utilized by Vearrier et al., 2005(Vearrier et al. 2005).

A very important aspect of biofeedback effectiveness and reproducibility is electrode placement (Hermens et al. 2000). Especially when small muscles are addressed, such as those from the face, forearm and hand, there is the possibility of providing the wrong information to the individual due to crosstalk. Neuromuscular re-education goal should be a selective muscle control(Novak 2004), which will not happen with an imprecise electrode placement. Important information such as the feedback modality, type of cue and BFB goal set(Kasman, Cram, and Wolf 1998; Criswell 2011; Lauber and Keller 2012) are mandatory to allow technique reproducibility. Besides, those parameters need to be investigated to decide when and what is best for PNI subjects.

BFB equipment has evolved greatly over the years. Initially their functioning was based on analogical data. In the 80s decade it was still possible to see oscilloscopes and speakers used to provide feedback (DenBrinker and Vanwieringen 1988). Later, digital processing allowed more sophisticated dispositive to increase the quality of biological signal presentation. This made easier to the patients to understand and use those signals as EBF. The possibility to choose different filter settings also allowed the practioner to properly adjust specific bandwidths to match more precisely to treatment goals. Another benefit of digital processing is a more precise common mode rejection ratio, which leads to less noise and a more consistent signal presentation(Criswell 2011). These differences among EBF equipment, whether they are ancient or modern, hamper comparisons between old and new studies.

New advances in EBF treatment should come with already existent technology. Such as creation of more complex games, use of virtual reality, addition of tracking and immersive technology. These will make EBF more realistic and even more motivating. Also, studies should include evaluations of how EBF neuroplastics changes take place, using neuroimaging or electrophysiological tools, for example.

This study had some important limitations regarding the homogeneity of the outcome measures and interventions, which prevented us to pool the results and dry more consistent conclusions. Afterward, some studies were not found even after we tried to personally contact the authors and journals, which impeded us to present a more comprehensive state of the art in this field.

Conclusion

There is no sufficient data to state EBF effectiveness in recovering motor function of PNI subjects. There are few studies of this nature and the majority of them have low quality study designs.

Compliance with Ethical Standards

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Conflict-of-Interest Statement

The authors declare that they have no conflict of interest.

Research involving human participants and/or animals

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Table 1. Included studies characteristics, clinical data, BFB dosage and results.

Author/Year	Design[a]	BFB Sample[b]	CG Sample[c]	Mean Age[d]	Sex	Time since injury	Intervention	Follow-up	Assessment	Results
Pourmomeny AA, 2015	RCT	BP with Synkinesis EBF = 17	EBF + BTX-A = 17	37,61 years	77,7% W	At least 6 months EBF = 5+6,93 years EBF + BTX-A = 3+40 years	3x/week 30'/session	4 months	Facial Grading Scale	Improvement No difference between groups
Pourmomeny AA, 2014	RCT	Acute FP =16 BP = 10 Trauma = 5 Tumor = 1	Routine Physiotherapy Acute FP = 13 BP = 9 Trauma = 3 Tumor = 1	NR 11-57 years	44,8% W	No more than 2 to 3 weeks of onset	5x/week for1 month 1x/week for 11 months 30'-45'/session	12 months	Facial Grading Scale	Improvement No difference between groups

Dalla Toffola E, 2012	Retrospective cohort study	Acute BP Axonotmesis EBF = 38	Acute BP Axonotmesis Mirror = 35 Neuropraxia No treatment = 29	48 years	38,2% W	No more than 1 month of onset	NR Personalised Mean EFB sessions = 13,5 Mean MF sessions = 20	12 months	House scale	Improvement No difference between groups
Dalla Toffola E, 2005	Retrospective cohort study	BP EBF = 37	BP ET = 28	43.8 years	33,8% W	No more than 1 month of onset	3-5x/week for ? 1-2x/week for ? 60'/session	12 months	House scale	EBF was significantly better than ET
Cronin GW, 2003	Retrospective cohort study	Chronic FP = 24 BP = 3 Tumor = 7 Trauma = 2 Surgery = 6	Chronic FP No treatment = 6	44 years	75% W	Mean of 32 months of onset (9 months – 13 years)	2-4x/month Mean of 8,8 months (3,3 – 15 months)	NR	May Facial Grading scale	Improvement No improvement in CG group (n= 5)

		Autoimmune = 6								
Thomas RE, 1993	Non-Randomized Control trial	CTS EBF = 5	CTS No treatment = 5	39,3 years	100% W	Not described	Treatment on Working days for 2 months 60'/session	2 months	Grip strength	There was no significant differences between groups
Ross B, 1992	RCT	Chronic FP EBF = 11 Total: BP = 4 Tumor = 25 Autoimmune = 2	Chronic FP = 20 Mirror = 13 No treatment = 7	49 years	51,6% W	Minimum of 18 months Mean = 4.4 years	2x/week for 2 weeks 1x/ week for 6 weeks 2x/month for 10 months Unclear if 60' or 90'/session	12 months	Linear movement measure-ments Facial expression. and synkinesis	Improvement No difference between treatment groups

[a] RCT, randomized control trial
[b] FP, facial paralysis; BP, Bell's Palsy; CTS, carpal tunnel syndrome; N, sample size.

[c] EBF, electromyographic biofeedback; MF, mirror feedback; BTX-A, botulin toxin A; CBI, cognitive behavior intervention; G1, low psychosocial risk factors receiving usual medical care; G2, high psychosocial risk factors receiving usual medical care; G3, high psychosocial risk factors that refused additional behavioral treatment; CG, control group

[d] NR, not reported

Table 2. Quality assessment of the included studies.

PEDro scale	**Pourmomeny et al., 2015**	**Pourmomeny et al., 2013**	**Hasenbring et al., 1999**	**Ross et al., 1991**
Eligibility	1	1	1	1
Randomization	1	1	1	1
Allocation concealment	0	0	0	0
Similar at baseline	1	1	1	1
Blinding of all subjects	0	0	0	0
Blinding of therapist	0	0	0	0
Blinding of assessor	1	1	0	1
More than 85%	0	0	0	1
Intention to treat	0	0	0	0
Between-group statistical comparison	1	1	1	1
Point and variability measurements	1	1	1	1
Total	5	5	4	6

4. CONCLUSÃO

- Evidência limitada para atestar a efetividade do BFB na recuperação da função motora de indivíduos com LNP
- É necessária a realização de ensaios clínicos controlados randomizados de alta qualidade

5. CONSIDERAÇÕES FINAIS

O resultado da revisão realça a necessidade de melhorar a qualidade de estudos que investigam o efeito do BFB na recuperação da função motora de indivíduos com LNP. Fica claro que a utilização do BFB no tratamento da LNP na prática clínica têm sido baseada em estudos com baixo nível de evidência. Porém, as mesmas limitações encontradas neste estudo também estão presentes em outras revisões que investigam o efeito de técnicas de reabilitação nesta população. O número pequeno de indivíduos incluídos nos estudos é devido a variedade de apresentações clínicas na LNP, logo são necessárias melhores estratégias de captação e metodologia mais robusta para aumentar a qualidade dos estudos.

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6. PERSPECTIVAS DO ESTUDO

Novos ensaios clínicos controlados e randomizados devem ser realizados para investigar o efeito do BFB na recuperação da função motora de sujeitos com diferentes tipos de LNP. As perguntas de investigação que devem ser respondidas são: O BFB tem efeito na função motora de indivíduos com LNP? Estas são clinicamente relevantes? O BFB é seguro, tem efeitos colaterais nesta população? Diferentes modalidades de feedback ou tipos de pistas produzem resultados diferentes? O efeito do BFB é modificado pela gravidade ou fase da doença?

7.0 ANEXOS

7.1 ANEXO A – ESTRATÉGIA DE BUSCA

(((biofeedback OR biofeedback emg OR emg biofeedback OR electromyography biofeedback OR electromyographic biofeedback OR muscle biofeedback OR feedback emg OR emg feedback OR electromyography feedback OR electromyographic feedback OR myo feedback OR biofeedback)) AND (neuromuscular disease OR peripheral nerve injury OR peripheral nerve lesion OR nerve lesion OR nerve injury OR nerve crush OR neurotization OR nerve transfer OR neurorrhaphy OR bell palsy OR bell idiopathic OR facial nerve OR median nerve OR ulnar nerve OR medial nerve OR femoral nerve OR fibular nerve OR sciatic OR isquiatic OR neuropathy OR neuropathies OR brachial plexus lesion)) NOT (laboratory animal study OR rats OR rat OR mouse OR mice OR habit OR stroke OR neurofeedback)))