



# EVIDENCE SEARCH RESULTS

<b>Question/subject of request:</b>	Use of upper limb neuro-muscular electrical stimulations (NMES), in the neurological population.
<b>Date requested:</b>	14/04/2025
<b>Date completed:</b>	20/05/2025
<b>Compiled by:</b>	Katy Kitto

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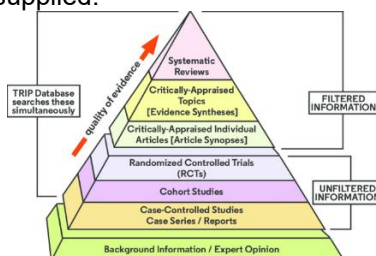
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# Journal Articles:

## **Longitudinal Retrospective Study of a Wearable NMES System to Determine the Effects on Arm Usage in Hemiparetic and Hemiplegic Patients.**

**Authors:** Muccio P.;Salama R.;Chopra N.;Schueller J.;Durrant D. and Dabrowski, E.

**Publication Date:** 2025

**Journal:** Journal of Prosthetics and Orthotics 37(1), pp. 53–63

**Abstract:** Introduction Brain disorders such as traumatic brain injury (TBI), stroke, cerebral palsy (CP), and surgical interventions can result in aberrant motor function in the contralateral limbs, resulting in paralysis, weakness, and/or spasticity. It is known that, in the short term, neuromuscular electrical stimulation (NMES), the application of low-level electrical currents to motor nerves to induce muscle contractions in paralyzed muscles, can stimulate affected muscle groups and increase arm mobility. However, there remains a paucity of longitudinal evidence examining NMES-mediated improvements of arm usage. Objective The aim of this study was to determine the effectiveness of a long-term BioSleeve intervention on the recovery of arm mobility in hemiparetic patients. Study Design The design of this study is a retrospective cohort study. Methods We examined self-reported arm usage in patients with 1) TBI, 2) stroke, 3) hemispherectomy, or 4) CP who wore Axiobionics' BioSleeve NMES device and compared this to arm usage achieved from years of conventional therapy. Results The device was well-tolerated. Patients reported an average increase in arm usage from 9.9% to 43.5%, with the TBI subcohort reporting a consistent increase in arm usage of 5.7% per year over the treatment period. Conclusions This study supports the literature suggesting that longitudinal NMES can be used to increase arm usage in hemiplegic patients. Clinical Relevance Statement This study supports the use of wearable NMES intervention in the treatment of arm hemiparesis.

**Access or request item here:** <https://libkey.io/10.1097/JPO.0000000000000508>

## **Technological interventions for the suppression of hand tremors: A literature review.**

**Authors:** Sankar K.;Subairdeen M.A. and Muthukrishnan, N. K.

**Publication Date:** 2025

**Journal:** Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine 239(3), pp. 266–285

**Abstract:** A tremor is a neurological disorder that results in trembling or shaking in one or more body parts. A thorough literature review was conducted to investigate the methods for suppressing tremors. We looked for articles published between 1995 and 2024 in the databases CINAHL (Cumulative Index to Nursing and Allied Health Literature), PubMed, Medline, Embase, Scopus, and Cochrane. Two thousand two hundred fifty distinct items were discovered after an extensive search. Based only on the title, 250 were included. Two hundred papers were deemed ineligible after the abstracts were assessed. The remaining 26 articles were shortlisted after screening titles and abstracts and categorized based on treatment methods for hand tremors. According to the study's findings, deep brain stimulation (DBS) and electrical stimulation both reduced tremors considerably. It was also evident that attenuation systems and passive devices lessen the effects of tremors; target tracking tasks can lessen physiological tremors in postural posture; ET may have better



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hand functions after cold water treatment than warm water or at baseline; and targeted ultrasound thalamotomy is an effective treatment for ET, as it improved quality of life (QoL) significantly. Additionally, the design, development, and evaluation of wearable devices and pharmaceutical interventions for tremor suppression were investigated in detail. The main objective was to perform a comparative analysis of the merits and demerits of both treatment methodologies in terms of functional outcomes, users' comfort, and side effects. The review highlights wearable devices as a beneficial option for tremor suppression, offering comfort, safety, and advanced technology over pharmaceutical intervention methodologies.

**Access or request item here:** <https://libkey.io/10.1177/09544119251325115>

### **Neuromuscular electrical stimulation producing low evoked force elicits the repeated bout effect on muscle damage markers of the elbow flexors**

**Authors:** Jeon, Sunggun; Sontag, Stephanie A.; Richardson, Lyric D.; Olmos, Alex A. and Trevino, Michael A.

**Publication Date:** 2025

**Journal:** Sports Medicine & Health Science (SMHS) 7(2), pp. 124–131

**Abstract:** This study examined the repeated bout effect (RBE) on muscle damage markers following two bouts of neuromuscular electrical stimulation (NMES) in untrained individuals. Following familiarization, participants received 45 consecutive NMES to the biceps brachii at an intensity that produced low evoked force for the elbow flexors. Muscle damage markers (maximal voluntary isometric contraction [MVIC], elbow range of motion [ROM], muscle soreness via visual analogue scale [VAS] scores, pressure pain threshold [PPT], and muscle thickness) were measured before (PRE), after (POST), 1 day after (24 POST), and 2 days after (48 POST) NMES. Following 1 week of rest, procedures were replicated. Separate repeated measures two-way ANOVAs examined each measure. There were no interactions or bout main effects for MVIC or ROM. Time main effects indicated PRE MVIC was greater than POST ( $p = 0.002$ ) and 24-POST ( $p = 0.024$ ), and PRE ROM was greater than POST ( $p = 0.036$ ). There was no interaction for muscle thickness. Respective time and bout main effects indicated muscle thickness at PRE was less than POST ( $p = 0.017$ ), and second-bout muscle thickness ( $p = 0.050$ ) was less compared to the initial-bout. For PPT, there was an interaction ( $p = 0.019$ ). Initial-bout PRE PPT was less than POST ( $p = 0.033$ ). Initial-bout 48-POST PPT was less than second-bout 48-POST ( $p = 0.037$ ). There was a significant interaction for VAS ( $p = 0.009$ ). Initial-bout PRE VAS was less than POST ( $p = 0.033$ ) and 24-POST ( $p = 0.015$ ). Initial-bout POST and 24-POST VAS were greater than second-bout POST ( $p = 0.023$ ) and 24-POST ( $p = 0.006$ ), respectively. The results support RBE on muscle damage markers related to inflammation, but not MVIC and ROM. ABSTRACT FROM AUTHOR]; Copyright of Sports Medicine & Health Science (SMHS) is the property of Chengdu Sport University and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

**Access or request item here:** <https://libkey.io/10.1016/j.smhs.2024.04.006>

### **Simplified control of neuromuscular stimulation systems for restoration of reach with limb stiffness as a modifiable degree of freedom**



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**Authors:** Johnson, Tyler R.;Haddix, Chase A.;Ajiboye, A. B. and Taylor, Dawn M.

**Publication Date:** 2025

**Journal:** Journal of Neural Engineering 22(3)

**Abstract:** Objective. Brain-controlled functional electrical stimulation (FES) of the upper limb has been used to restore arm function to paralyzed individuals in the lab. Able-bodied individuals naturally modulate limb stiffness throughout movements and in anticipation of perturbations. Our goal is to develop, via simulation, a framework for incorporating stiffness modulation into the currently-used 'lookup-table-based' FES control systems while addressing several practical issues: (1) optimizing stimulation across muscles with overlap in function, (2) coordinating stimulation across joints, and (3) minimizing errors due to fatigue. Our calibration process also needs to account for when current spread causes additional muscles to become activated. Approach. We developed an analytical framework for building a lookup-table-based FES controller and simulated the clinical process of calibrating and using the arm. A computational biomechanical model of a human paralyzed arm responding to stimulation was used for simulations with six muscles controlling the shoulder and elbow in the horizontal plane. Both joints had multiple muscles with overlapping functional effects, as well as biarticular muscles to reflect complex interactions between joints. Performance metrics were collected in silico, and real-time use was demonstrated with a Rhesus macaque using its cortical signals to control the computational arm model in real time. Main results. By explicitly including stiffness as a definable degree of freedom in the lookup table, our analytical approach was able to achieve all our performance criteria. While using more empirical data during controller parameterization produced more accurate lookup tables, interpolation between sparsely sampled points (e.g. 20° angular intervals) still produced good results with median endpoint position errors of less than 1 cm—a range that should be easy to correct for with real-time visual feedback. Significance. Our simplified process for generating an effective FES controller now makes translating upper limb FES systems into mainstream clinical practice closer to reality. (Creative Commons Attribution license.)

**Access or request item here:** <https://libkey.io/10.1088/1741-2552/adc9e3>

### **The Clinical Management of Electrical Stimulation Therapies in the Rehabilitation of Individuals with Spinal Cord Injuries**

**Authors:** Dolbow, David R.;Bersch, Ines;Gorgey, Ashraf S. and Davis, Glen M.

**Publication Date:** 2024

**Journal:** Journal of Clinical Medicine 13(10), pp. 2995

**Abstract:** Background: People with spinal cord injuries (SCIs) often have trouble remaining active because of paralysis. In the past, exercise recommendations focused on the non-paralyzed muscles in the arms, which provides limited benefits. However, recent studies show that electrical stimulation can help engage the paralyzed extremities, expanding the available muscle mass for exercise. Methods: The authors provide an evidence-based approach using expertise from diverse fields, supplemented by evidence from key studies toward the management of electrical stimulation therapies in individuals with SCIs. Literature searches were performed separately using the PubMed, Medline, and Google Scholar search engines. The keywords used for the searches included functional electrical stimulation cycling, hybrid cycling, neuromuscular electrical stimulation exercise, spinal cord injury, cardiovascular health, metabolic health, muscle strength, muscle mass, bone mass, upper limb treatment, diagnostic and prognostic use of functional electrical stimulation, tetraplegic hands, and hand deformities after SCI. The authors recently presented this



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information in a workshop at a major rehabilitation conference. Additional information beyond what was presented at the workshop was added for the writing of this paper. Results: Functional electrical stimulation (FES) cycling can improve aerobic fitness and reduce the risk of cardiovascular and metabolic diseases. The evidence indicates that while both FES leg cycling and neuromuscular electrical stimulation (NMES) resistance training can increase muscle strength and mass, NMES resistance training has been shown to be more effective for producing muscle hypertrophy in individual muscle groups. The response to the electrical stimulation of muscles can also help in the diagnosis and prognosis of hand dysfunction after tetraplegia. Conclusions: Electrical stimulation activities are safe and effective methods for exercise and testing for motor neuron lesions in individuals with SCIs and other paralytic or paretic conditions. They should be considered part of a comprehensive rehabilitation program in diagnosing, prognosing, and treating individuals with SCIs to improve function, physical activity, and overall health. ABSTRACT FROM AUTHOR]; Copyright of Journal of Clinical Medicine is the property of MDPI and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

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## TCES for Upper Limb Function in Cervical SCI

**Publication Date:** 2024

University of Leeds.

**Abstract:** Following a cervical spinal cord injury (cSCI; damage to the spinal cord at the neck) there is catastrophic loss of hand and grip function. This has a devastating effect on quality of life and functional independence. Thus, there is a real need to identify and optimise therapy to aid functional arm and hand recovery. One such therapy is Transcutaneous Electrical Stimulation (tCES). This involves applying sticky pads to the skin and then transmitting a low-level electrical current to the spinal cord. This activates neural circuits, allowing injured nerves to transmit signals to muscles to produce movement while completing upper limb tasks. The purpose of this pilot project is to establish if and how tCES might be used to improve arm and hand control. The investigators will recruit 8 people who have had a cSCI for >1yr. First, the investigators will invite volunteers to the University for 2 weeks, twice per week, to establish their baseline movement capacity. Then the investigators will allocate the volunteers to one of two groups: group 1 will undertake 4 weeks of upper limb task practice (ULTP) followed by 4 weeks of ULTP+tCES; group 2 will undertake ULTP+tCES for 4 weeks followed by 4 weeks of ULTP. Participants will then complete a week (2 sessions) of post-intervention assessment. The investigators will then invite volunteers and carers to be interviewed about their experiences of being involved in the project. Finally, there will be 2 sessions of follow-up assessment after 3 months. In order to assess if and how ULTP+tCES affects arm and hand control the investigators will measure: movement capacity using standard clinical tests; muscular activity in response to brain/spinal stimulation; how fast and smooth movements are when reaching and grasping objects. The investigators will also examine how the intervention has affected Quality of Life (QoL) and independence (Spinal Cord Independence Measure).; Spinal cord injury (SCI) can be defined as a loss of communication between the brain and the body due to damage to pathways within the spinal cord. Injury to the cervical levels of the spinal cord are more common than injury to the lower segments of the spinal cord, thus tetraplegia is more



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common than paraplegia (Thompson et al., 2014). Tetraplegics rank regaining arm and hand function as their main priority for rehabilitation, five times greater than bowel, bladder, sexual or lower extremity function (Anderson, 2004). However, compared to recent advances made in recovery of ambulatory function, research that strives to uncover how best to optimise arm/hand rehabilitation after SCI is very limited. Thus identifying and optimising efficacious therapies to restore functional arm and hand recovery is an important clinical, economic and social goal. While promising molecular strategies have emerged to reduce secondary injury and promote axonal regrowth, an effective cure eludes people with cervical SCI, and overall recovery of arm and hand function using these means remains limited (Levi et al., 2018). Functional training, or task specific training of a motor function (e.g. reaching and grasping), is currently the most effective evidence-based way of enhancing plasticity to recover motor function. A promising approach is the use of stimulation-based rehabilitative therapies promoting neural plasticity along the spinal cord/corticospinal tract. Among these, transcutaneous electrical stimulation (TCES) (Gerasimenko et al., 2015) was demonstrated to be effective for improving hand grip strength in people with spinal cord injury (Gad et al., 2018). The investigators hypothesise that combining upper limb practice (ULTP) and TCES to the cervical spinal cord over the course of 4 weeks, could affect arm/ hand function and quality of life to a greater extent than ULTP by itself. The principal aim of the study is to test the effects of transcutaneous electrical stimulation on arm and hand functions in individuals with cervical spinal cord injury. In addition, the investigators aim to assess the neurophysiological mechanisms with which transcutaneous electrical stimulation supports the observed changes in hand/arm function. The primary objective of the study is to measure and compare the changes in hand and arm functions, assessed through the Graded and Redefined Assessment of Strength, Sensibility and Prehension test (GRASSP) tool, occurring over the course of the two interventions (ULTP and ULTP + TCES). In addition, secondary objectives are: To explain the neurophysiological mechanisms with which transcutaneous electrical stimulation results in changes in hand/arm function. To establish a clearly defined, reproducible protocol for establishing participant specific TCES settings. To understand factors that contribute to participants wanting to use TCES and their experience of using TCES. The study will consist of two weeks of baseline measurements, 8 weeks of intervention (4 weeks of ULTP and 4 weeks of TCES + ULTP) in a cross-over design, followed by two-weekly and a 3 month follow-up with no further intervention (Inanici et al., 2018). The baseline measurements (see primary and secondary outcome measures) are necessary to document stability of functional status. Baseline measures will take place over 2 sessions, each week (e.g. 4 baseline testing sessions). Participation to the study will span over the course of 25 weeks. On the first 2 weeks, participants will attend the lab twice per week. On the following 8 weeks, participants will attend the lab three times per week. On week 11, participants will attend the lab twice. On week 12, participants and their carers will be invited to a semi-structured interview. There will then be a 3-months break during which the participants are not required to attend the lab, after which (week 25) they will take part on two follow-up sessions.

### **Wrist posture unpredictably affects perception of targeted transcutaneous electrical nerve stimulation with wrist-placed electrodes**

**Authors:** Thomas, Neha; Osborn, Luke; Moran, Courtney; Fifer, Matthew and Christie, Breanne

**Publication Date:** 2024

**Journal:** Frontiers in Neuroscience , pp. 1–11

**Abstract:** Objective: Targeted transcutaneous electrical nerve stimulation (tTENS) is a non-



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invasive neural stimulation technique that involves activating sensory nerve fibers to elicit tactile sensations in a distal, or referred, location. Though tTENS is a promising approach for delivering haptic feedback in virtual reality or for use by those with somatosensory deficits, it was not known how the perception of tTENS might be influenced by changing wrist position during sensorimotor tasks. Approach: We worked with 12 able-bodied individuals and delivered tTENS by placing electrodes on the wrist, thus targeting the ulnar, median, and radial nerves, and eliciting tactile sensations in the hand. We recorded perceptual data across three wrist postures: neutral, 45° extension, and 45° flexion. For each posture, the participants drew where they perceived the elicited percepts on a map of the hand. They verbally reported the quality of the percepts in their own words. We also varied the pulse amplitude and width of the stimulation to generate a strength-duration curve, from which we extracted the rheobase current and chronaxie time. Linear mixed models were run on the slope and intercept of the linear fit between pulse width and pulse amplitude to investigate effects of gender, posture, and electrode placement. Main results: As wrist posture changed, sensation quality was modulated for half of the participants, and percept location changed for 11/12 participants. The rheobase, chronaxie, and percept sizes were influenced by wrist posture, but the direction of these changes varied by participant and therefore the effect was not systematic. The statistical models indicated interactions between posture and electrode placement, as well as an effect of gender. Significance: If using tTENS with electrodes placed on the wrist to convey haptic feedback during sensorimotor tasks, in which wrist posture will likely change, it may be important to characterize perception on an individual basis. ABSTRACT FROM AUTHOR]; Copyright of Frontiers in Neuroscience is the property of Frontiers Media S.A. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

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### **Paired Associative Stimulation Improves Motor Function in the Upper Extremity in Chronic Incomplete Spinal Cord Injury: a Corroborative Study**

**Authors:** WAHLGREN, Carl; LEVI, Richard and THORDSTEIN, Magnus

**Publication Date:** 2024

**Journal:** Journal of Rehabilitation Medicine (Stiftelsen Rehabiliteringsinformation) 56, pp. 1–9

**Abstract:** Objective: To corroborate findings suggesting that spinally targeted paired associative stimulation improves upper extremity motor function in chronic incomplete spinal cord injury. Design: Prospective interventional study. Subjects: Five adults with chronic tetraplegia. Methods: Participants received paired associative stimulation, combining peripheral nerve stimulation and navigated transcranial magnetic stimulation towards 1 arm (16 1-h sessions during 4 consecutive weeks, targeting the 3 large nerves). Manual muscle testing (MMT) was performed in 23 muscles in each arm, at 3 time points (pre-stimulation, t0; the week following the stimulation period, t1; and 4-5 weeks post-stimulation, t2). Additionally, grip strength and changes in the Canadian Occupational Performance Measure were assessed. Results: The mean improvement in manual muscle testing scores in the targeted extremity was +0.49 at t1 ( $p = 0.078$ ) and +0.55 at t2 ( $p = 0.062$ ). Grip strength in the stimulated extremity increased by 3.2 kg at t1 and 3.4 kg at t2, and in the non-targeted



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extremity by 2.2 and 3.6 kg, respectively. Performance and satisfaction increased by 2.1/2.4 points at t1, and by 2.0/1.9 points at t2. Conclusion: Paired associative stimulation improved motor function: at the group level, MMT of the stimulated hand ( $p = 0.06$ ) and non-stimulated hand ( $p = 0.04$ ). Most participants achieved clinically relevant improvement. Thus, the results corroborate prior studies. The method may complement conventional rehabilitation for improving upper extremity function in incomplete tetraplegia.

**Access or request item here:** <https://libkey.io/10.2340/jrm.v56.41021>

### **Contralaterally Controlled Functional Electrical Stimulation for Improving Motor Function After Acquired Brain Injury: A Systematic Review and Meta-analysis**

**Authors:** Xie, Shan;Zhang, Yuqian;Li, Jing;Wu, Zhefan and Bai, Yulong

**Publication Date:** 2024

**Journal:** Archives of Physical Medicine & Rehabilitation 105(12), pp. 2327–2335

**Abstract:** To systematically evaluate the effect of contralaterally controlled functional electrical stimulation (CCFES) on motor function after acquired brain injury (ABI). We searched the PubMed, Embase, Cochrane Central Register of Controlled Trials, Physiotherapy Evidence Database (PEDro), Web of Science, SinoMed, CNKI, VIP Database for Chinese Technical Periodicals and Wanfang Database, from inception to December 2023. Studies were included if they were randomized controlled trials assessing the effect of CCFES on motor function compared with routine rehabilitation or routine electrical stimulation after ABI. Two independent reviewers screened 894 articles for inclusion. The extracted data included study information, sample size, study population, interventions, measurement evaluated, and the test interval. This study included 24 trials with 28 intervention-control pairs and 1148 participants with stroke. Meta-analysis showed that the CCFES group demonstrated more significant improvement than the control group in the Fugl-Meyer Assessment Scale (FMA) (standardized mean difference SMD]=0.66, 95% confidence interval CI]=0.44-0.88,  $P < .001$ ), active range of motion (AROM) (SMD=0.77, 95% CI=0.54-1.01,  $P < .001$ ), modified Barthel Index (MBI) (SMD=0.55, 95% CI=0.29-0.81,  $P < .001$ ), Motricity Index (MI) (SMD=0.60, 95% CI=0.26-0.94,  $P < .001$ ) surface electromyography (sEMG) (SMD=0.81, 95% CI=0.56-1.06,  $P < .001$ ), and Functional Ambulation Category (FAC) (SMD=0.53, 95% CI=0.24-0.83,  $P < .001$ ). The CCFES group showed no significant improvement over the control group in the Action Research Arm Test (ARAT) (SMD=0.24, 95% CI=-0.10-0.58,  $P = .17$ ). Our synthesized evidence suggests that CCFES could improve motor function in patients with stroke. More RCTs with other patients with brain injury are required to provide future evidence on the therapy effect of CCFES and make a contribution to the uniform standard of CCFES.

**Access or request item here:** <https://libkey.io/10.1016/j.apmr.2024.03.001>

### **Research on Tremor Suppression Strategies Under a Constant Current Peripheral Electrical Stimulation Device for Parkinson's Disease**

**Authors:** Gong, Kening;Guo, Chuangqiang;Guo, Weihang;Jiang, Li and Liu, Hong

**Publication Date:** 2024

**Journal:** IEEE Transactions on Neural Systems & Rehabilitation Engineering 32, pp. 3071–3083

**Abstract:** Tremor, a prevalent symptom in Parkinson's patients, is conventionally treated with medications and craniotomy. However, the associated side effects and high surgical costs pose challenges for some individuals. In this study, a lightweight constant current





electrical stimulator was developed, which is driven by the FPGA to control the underlying logic and has multiple programmable stimulation parameters. Clinical experiments involving patients with Parkinson's-related resting tremor symptoms were conducted to assess the efficacy of peripheral electrical stimulation. Two Co-contraction Avoidance Stimulation (CAS) strategies targeting nerves and muscles were proposed to reduce tremors. Four Parkinson's disease (PD) patients were recruited to verify the effectiveness of these strategies. Kinematic data recorded by inertial sensors showed that the radial nerve and muscle intervention strategies reduced the average angular velocity amplitude of finger joints during resting tremor by 75.92% and 82.41%, respectively. Notably, under low-frequency pulse stimulation (100 Hz) focused on muscle interference, a low-intensity current of no more than 8 mA maintained a tremor suppression rate of 59.91% even 5 minutes post-stimulation. Based on the experimental results, it is concluded that the constant current electrical stimulator developed in this study can effectively suppress tremor under specific stimulation strategies. These findings have significant implications for the development of lightweight, wearable tremor suppression devices. The stimulator's adaptability, coupled with its precise control parameters, demonstrates promise for advancing non-invasive and cost-effective tremor management in Parkinson's patients. ABSTRACT FROM AUTHOR]; Copyright of IEEE Transactions on Neural Systems & Rehabilitation Engineering is the property of IEEE and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

**Access or request item here:** <https://libkey.io/10.1109/TNSRE.2024.3435749>

### **Functional electrical stimulation therapy for upper extremity rehabilitation following spinal cord injury: a pilot study.**

**Authors:** Balbinot G.;Li G.;Gauthier C.;Musselman K.E.;KalsiRyan S. and Zariffa, J.

**Publication Date:** 2023

**Journal:** Spinal Cord Series and Cases 9(1) (pagination), pp. Article Number: 11. Date of Publication: 01 Dec 2023

**Abstract:** Study design: Pilot study.

**Access or request item here:** <https://libkey.io/10.1038/s41394-023-00568-4>

### **Testing a Novel Wearable Device for Motor Recovery of the Elbow Extensor Triceps Brachii in Chronic Spinal Cord Injury.**

**Authors:** Germann M. and Baker, S. N.

**Publication Date:** 2023

**Journal:** eNeuro 10(7) (pagination), pp. Article Number: ENEURO.0077-23.2023. Date of Publication: 01 Jul 2023

**Abstract:** After corticospinal tract damage, reticulospinal connections to motoneurons strengthen preferentially to flexor muscles. This could contribute to the disproportionately poor recovery of extensors often seen after spinal cord injury (SCI) and stroke. In this study, we paired electrical stimulation over the triceps muscle with auditory clicks, using a wearable device to deliver stimuli over a prolonged period of time. Healthy human volunteers wore the stimulation device for ~6 h and a variety of electrophysiological assessments were used to



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measure changes in triceps motor output. In contrast to previous results in the biceps muscle, paired stimulation: (1) did not increase the StartReact effect; (2) did not decrease the suppression of responses to transcranial magnetic brain stimulation (TMS) following a loud sound; (3) did not enhance muscle responses elicited by a TMS coil oriented to induce anterior-posterior current. In a second study, chronic cervical SCI survivors wore the stimulation device for ~4 h every day for four weeks; this was compared with a four-week period without wearing the device. Functional and electrophysiological assessments were repeated at week 0, week 4, and week 8. No significant changes were observed in electrophysiological assessments after paired stimulation. Functional measurements such as maximal force and variability and speed of trajectories made during a pla-nar reaching task also remained unchanged. Our results suggest that the triceps muscle shows less potential for plasticity than biceps; pairing clicks with muscle stimulation does not seem beneficial in enhancing triceps recovery after SCI.

**Access or request item here:** <https://libkey.io/10.1523/ENEURO.0077-23.2023>

### **Effects Of Functional Electrical Stimulation Versus Upper Limb Loading Exercises on Grip Strength,Dexterity and Function in Patients With Spinal Cord Injury.**

**Publication Date:** 2023

**Journal:** Clinicaltrials.Gov (pagination), pp. Date of Publication: 09 May 2023

**Abstract:** Brief Summary This study is conducted to assess the effectiveness of functional electrical stimulation Vs limb loading exercises on hand grip strength,dexterity and function in patients with subacute cervical spinal cord injury. Detailed Description Spinal cord injury (SCI) is based on the concept that rehabilitative training recruits neuronal systems spinal cord injury that remain intact after the injury to take over the impaired function.Working in the field of rehabilitation of the spinal cord injured, presents many challenges. Every patient presents a new and specific challenge. The tetraplegics more so than the paraplegics as the result of loss of active function of their upper extremities in addition to loss of function in the trunk and lower extremities. This study will be conducted to assess the effects of functional electrical stimulation versus limb loading exercises on hand grip strength,dexterity and function in patients with subacute spinal cord injury. trength,dexterity and function in patients with subacute spinal cord injury. The study will be randomized clinical trial. Participants will be randomly allocated in to two groups each group will have ten participants.. This study will be conducted in two Hospitals in Punjab pakistan. The group A Will receive functional electrical stimulation .The group B will receive upper limb loading exercises .Both groups will be given 30-45 min session 5 days per week for 8 weeks. The outcomes will be measured before and after giving treatment by using modified Action Research Arm Test (ARAT),Hand held dynamometry , Nine-Hole Peg Test (9HPT). The results will be calculated by using SPSS 23 version . Statistical tests will be applied according to the normality of the data either it will be parametric or non-parametric.

### **Electrical Stimulation Exercise for People with Spinal Cord Injury: A Healthcare Provider Perspective**

**Authors:** Dolbow, David R.;Gorgey, Ashraf S.;Johnston, Therese E. and Bersch, Ines

**Publication Date:** 2023

**Journal:** Journal of Clinical Medicine 12(9), pp. 3150



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**Abstract:** Electrical stimulation exercise has become an important modality to help improve the mobility and health of individuals with spinal cord injury (SCI). Electrical stimulation is used to stimulate peripheral nerves in the extremities to assist with muscle strengthening or functional activities such as cycling, rowing, and walking. Electrical stimulation of the peripheral nerves in the upper extremities has become a valuable tool for predicting the risk of hand deformities and rehabilitating functional grasping activities. The purpose of this paper is to provide healthcare providers perspective regarding the many rehabilitation uses of electrical stimulation in diagnosing and treating individuals with SCI. Electrical stimulation has been shown to improve functional mobility and overall health, decrease spasticity, decrease the risk of cardiometabolic conditions associated with inactivity, and assist in the diagnosis/prognosis of hand deformities in those with tetraplegia. Studies involving non-invasive stimulation of the spinal nerves via external electrodes aligned with the spinal cord and more invasive stimulation of electrodes implanted in the epidural lining of the spinal cord have demonstrated improvements in the ability to stand and enhanced the stepping pattern during ambulation. Evidence is also available to educate healthcare professionals in using functional electrical stimulation to reduce muscle spasticity and to recognize limitations and barriers to exercise compliance in those with SCI. Further investigation is required to optimize the dose-response relationship between electrical stimulation activities and the mobility and healthcare goals of those with SCI and their healthcare providers. ABSTRACT FROM AUTHOR]; Copyright of Journal of Clinical Medicine is the property of MDPI and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

**Access or request item here:** <https://libkey.io/10.3390/jcm12093150>

### **Early Neuromuscular Electrical Stimulation Preserves Muscle Size and Quality and Maintains Systemic Levels of Signaling Mediators of Muscle Growth and Inflammation in Patients with Traumatic Brain Injury: A Randomized Clinical Trial**

**Authors:** Vieira, Luciana;Silva, Paulo Eugênio;de Melo, Priscilla Flavia;Maldaner, Vinicius;Durigan, Joao Q.;Marqueti, Rita de Cassia;Nobrega, Otavio;Mathur, Sunita;Burtin, Chris;Barin, Fabrício;Machado-Silva, Wilcelly;Ramalho, Sergio;Chiappa, Gaspar R.;Gomes, Nadia Oliveira;Carvalho, Celso R. F.;Cipriano, Graziella F. B. and Cipriano, Gerson

**Publication Date:** 2023

**Journal:** Critical Care Research & Practice , pp. 1–12

**Abstract:** Objective. To investigate the effects of an early neuromuscular electrical stimulation (NMES) protocol on muscle quality and size as well as signaling mediators of muscle growth and systemic inflammation in patients with traumatic brain injury (TBI). Design. Two-arm, single-blinded, parallel-group, randomized, controlled trial with a blinded assessment. Setting. Trauma intensive care unit at a university hospital. Participants. Forty consecutive patients on mechanical ventilation (MV) secondary to TBI were prospectively recruited within the first 24 hours following admission. Interventions. The intervention group (NMES; n = 20) received a daily session of NMES on the rectus femoris muscle for five consecutive days (55 min/each session). The control group (n = 20) received usual care. Main Outcome Measures. Muscle echogenicity and thickness were evaluated by ultrasonography. A daily blood sample was collected to assess circulating levels of insulin-like growth factor I (IGF-I), inflammatory cytokines, and matrix metalloproteinases (MMP).



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Results. Both groups were similar at baseline. A smaller change in muscle echogenicity and thickness (difference between Day 1 and Day 7) was found in the control group compared to the NMES group ( $29.9 \pm 2.1$  vs.  $3.0 \pm 1.2$ ,  $p < 0.001$ ;  $-0.79 \pm 0.12$  vs.  $-0.01 \pm 0.06$ ,  $p < 0.001$ , respectively). Circulating levels of IGF-I, pro-inflammatory cytokines (IFN- $\gamma$ ), and MMP were similar between groups. Conclusion. An early NMES protocol can preserve muscle size and quality and maintain systemic levels of signaling mediators of muscle growth and inflammation in patients with TBI. This trial is registered with <https://www.ensaiosclinicos.gov.br> under number RBR-2db. ABSTRACT FROM AUTHOR]; Copyright of Critical Care Research & Practice is the property of Wiley-Blackwell and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.)

**Access or request item here:** <https://libkey.io/10.1155/2023/9335379>

### **Activating effective functional hand movements in individuals with complete tetraplegia through neural stimulation.**

**Authors:** Coste C.A.;William L.;Fonseca L.;Hiarrassary A.;Andreu D.;Geffrier A.;Teissier J.;Fattal C. and Guiraud, D.

**Publication Date:** 2022

**Journal:** Scientific Reports 12(1), pp. 16189

**Abstract:** Individuals with complete cervical spinal cord injury suffer from a permanent paralysis of upper limbs which prevents them from achieving most of the activities of daily living. We developed a neuroprosthetic solution to restore hand motor function. Electrical stimulation of the radial and median nerves by means of two epineural electrodes enabled functional movements of paralyzed hands. We demonstrated in two participants with complete tetraplegia that selective stimulation of nerve fascicles by means of optimized spreading of the current over the active contacts of the multicontact epineural electrodes induced functional and powerful grasping movements which remained stable over the 28 days of implantation. We also showed that participants were able to trigger the activation of movements of their paralyzed limb using an intuitive interface controlled by voluntary actions and that they were able to perform useful functional movements such as holding a can and drinking through a straw.

**Access or request item here:** <https://libkey.io/10.1038/s41598-022-19906-x>

### **Deep Reinforcement Learning for Control of Time-Varying Musculoskeletal Systems With High Fatigability: A Feasibility Study.**

**Authors:** Abreu J.;Crowder D.C. and Kirsch, R. F.

**Publication Date:** 2022

**Journal:** IEEE Transactions on Neural Systems and Rehabilitation Engineering 30, pp. 2613–2622

**Abstract:** Functional electrical stimulation (FES) can be used to restore motor function to people with paralysis caused by spinal cord injuries (SCIs). However, chronically-paralyzed FES-stimulated muscles can fatigue quickly, which may decrease FES controller performance. In this work, we explored the feasibility of using deep neural network (DNN) controllers trained with reinforcement learning (RL) to control FES of upper-limb muscles



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after SCI. We developed upper-limb biomechanical models that exhibited increased muscle fatigability, decreased muscle recovery, and decreased muscle strength, as observed in people with chronic SCIs. Simulations confirmed that controller training time and controller performance are impaired to varying degrees by muscle fatigability. Also, the simulations showed that large muscle strength asymmetries between opposing muscles can substantially impair controller performance. However, the results of this study suggest that controller performance for highly-fatigable musculoskeletal systems can be preserved by allowing for rest between movements. Overall, the results suggest that RL can be used to successfully train FES controllers, even for highly-fatigable musculoskeletal systems.

**Access or request item here:** <https://libkey.io/10.1109/TNSRE.2022.3203970>

### **Mechanomyography and tissue oxygen saturation during electrically-evoked wrist extensor fatigue in people with tetraplegia**

**Authors:** Mohamad Saadon, Nurul Salwani;Hamzaid, Nur Azah;Hasnan, Nazirah;Dzulkifli, Muhammad Afiq;Teoh, Mira and Davis, Glen M.

**Publication Date:** 2022

**Journal:** Artificial Organs 46(10), pp. 1998–2008

**Abstract:** Background: Repetitive electrically-evoked muscle contractions lead to the early onset of muscle fatigue. This study assessed the relationship between muscle mechanomyography (%RMS-MMG) and tissue oxygen saturation (%TSI) in extensor carpi radialis (ECR) during electrically-evoked fatiguing exercise in individuals with tetraplegia.; Methods: Skin-surface mechanomyography (MMG) and near-infrared spectroscopy (NIRS) sensors were placed on the ECR of seven individuals with tetraplegia. All participants performed repetitive electrically-evoked wrist extension to fatigue while their muscle MMG and NIRS responses were monitored against their power output (PO).; Findings: One out of seven participants showed no changes in %TSI throughout the repeated wrist FES-evoked contraction. The other six participants' %TSI was positively correlated with %PO before fatigue onset. At 50%PO peak, %TSI was negatively correlated (0.489) significantly with declining %PO as the ability of the muscle to take up oxygen became limited. The %RMS-MMG behaved analogously during pre and post-fatigue against declining %PO, whereby both displayed positive correlations of 0.443 and 0.214, respectively, (%RMS-MMG decreased) throughout the exercise session. Regression analysis revealed that %TSI was proportional to pre-fatigue and inversely proportional to %RMS-MMG during post-fatigue.; Conclusion: The significant changes in muscle mechanomyography and tissue oxygenation correlations after 50%PO peak implied that the muscle contraction mechanical-and-physiological behavior association had been altered following FES-evoked fatigue. (© 2022 International Center for Artificial Organ and Transplantation (ICAOT) and Wiley Periodicals LLC.)

**Access or request item here:** <https://libkey.io/10.1111/aor.14329>

### **Improving Upper Extremity Strength, Function, and Trunk Stability Using Wide-Pulse Functional Electrical Stimulation in Combination With Functional Task-Specific Practice**

**Authors:** Tefertiller C.;Bartelt P.;Stobelaar M.;Charlifue S.;Sevigny M.;Vande Griend E. and Rozwod, M.

**Publication Date:** 2022



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**Journal:** Topics in Spinal Cord Injury Rehabilitation 28(2), pp. 139–152

**Abstract:** Objectives: To evaluate upper extremity (UE) function, strength, and dynamic sitting balance in individuals with spinal cord injury (SCI) who received an intensive outpatient therapy program focused on UE training augmented with wide pulse/high frequency functional electrical stimulation (WPHF-FES).

**Access or request item here:** <https://libkey.io/10.46292/sci21-00004>

**Treatment with electrical stimulation of sensory nerves improves motor function and disability status in persons with multiple sclerosis: A pilot study.**

**Authors:** Alenazy M.;Daneshgar Asl S.;Petrigna L.;Feka K.;Alvarez E.;Almuklass A.M. and Enoka, R. M.

**Publication Date:** 2021

**Journal:** Journal of Electromyography and Kinesiology 61(pagination), pp. Article Number: 102607. Date of Publication: December 2021

**Abstract:** Declines in motor function are closely associated with decreases in sensory function in multiple sclerosis (MS). The purpose of our study was to assess the changes in motor function and disability status elicited by transcutaneous electrical nerve stimulation (TENS) to limb muscles of individuals with MS. Fifteen persons with MS and 11 age-matched healthy controls were evaluated before and after receiving 9 treatment sessions during which TENS was applied over the tibialis anterior and rectus femoris muscles of each leg, and over the median nerve and the thenar eminence of each hand. Each evaluation session involved completing two questionnaires (fatigue and walking limitations) and assessing walking performance (2-min test and 25-ft test), dynamic balance (chair-rise test), manual dexterity (grooved pegboard test), and muscle function of hands and legs (strength and force steadiness tests). The MS group exhibited improvements in the 25-ft test ( $P = 0.001$ ), 2-min test ( $P = 0.002$ ), chair-rise test ( $P = 0.008$ ), grooved pegboard test ( $P = 0.008$ ), and reductions in the self-reported levels of fatigue and walking limitation scores ( $P = 0.02$ ,  $d = 0.52$ ;  $P = 0.008$ ,  $r = 0.50$  respectively). In contrast, there were no statistically significant changes in the Control group. There were no significant changes in either muscle strength or force steadiness for either group. TENS elicited significant improvements in motor function and self-reported disability status in persons with MS. Some improvements reached clinically meaningful levels.

**Access or request item here:** <https://libkey.io/10.1016/j.jelekin.2021.102607>

**Electrical stimulation alters muscle morphological properties in denervated upper limb muscles.**

**Authors:** Bersch I. and Friden, J.

**Publication Date:** 2021

**Journal:** eBioMedicine 74(pagination), pp. Article Number: 103737. Date of Publication: December 2021

**Abstract:** Background: Damage to lower motor neuron causes denervation and degeneration of the muscles affected. Experimental and clinical studies of muscle denervation in lower extremities demonstrated that direct electrical stimulation (ES) of muscle can prevent denervation atrophy and restore contractility. The aim of this study was to identify possible myogenic effect of ES on denervated forearm and hand muscles in persons with spinal cord injury (SCI) and tetraplegia.





Access or request item here: <https://libkey.io/10.1016/j.ebiom.2021.103737>

**On the way home: a BCI-FES hand therapy self-managed by sub-acute SCI participants and their caregivers: a usability study**

**Authors:** Zulauf-Czaja, Anna;Al-Taleb, Manaf;Purcell, Mariel;Petric-Gray, Nina;Cloughley, Jennifer and Vuckovic, Aleksandra

**Publication Date:** 2021

**Journal:** Journal of NeuroEngineering & Rehabilitation (JNER) 18(1), pp. 1–18

**Abstract:** Background: Regaining hand function is the top priority for people with tetraplegia, however access to specialised therapy out with clinics is limited. Here we present a system for hand therapy based on brain-computer interface (BCI) which uses a consumer grade electroencephalography (EEG) device combined with functional electrical stimulation (FES), and evaluate its usability among occupational therapists (OTs) and people with spinal cord injury (SCI) and their family members. Methods: Users: Eight people with sub-acute SCI (6 M, 2F, age  $55.4 \pm 15.6$ ) and their caregivers (3 M, 5F, age  $45.3 \pm 14.3$ ); four OTs (4F, age  $42.3 \pm 9.8$ ). User Activity: Researchers trained OTs; OTs subsequently taught caregivers to set up the system for the people with SCI to perform hand therapy. Hand therapy consisted of attempted movement (AM) of one hand to lower the power of EEG sensory-motor rhythm in the 8-12 Hz band and thereby activate FES which induced wrist flexion and extension. Technology: Consumer grade wearable EEG, multichannel FES, custom made BCI application. Location: Research space within hospital. Evaluation: donning times, BCI accuracy, BCI and FES parameter repeatability, questionnaires, focus groups and interviews. Results: Effectiveness: The BCI accuracy was 70-90%. Efficiency: Median donning times decreased from 40.5 min for initial session to 27 min during last training session (N = 7), dropping to 14 min on the last self-managed session (N = 3). BCI and FES parameters were stable from session to session. Satisfaction: Mean satisfaction with the system among SCI users and caregivers was  $3.68 \pm 0.81$  (max 5) as measured by QUEST questionnaire. Main facilitators for implementing BCI-FES technology were "seeing hand moving", "doing something useful for the loved ones", good level of computer literacy (people with SCI and caregivers), "active engagement in therapy" (OT), while main barriers were technical complexity of setup (all groups) and "lack of clinical evidence" (OT). Conclusion: BCI-FES has potential to be used as at home hand therapy by people with SCI or stroke, provided it is easy to use and support is provided. Transfer of knowledge of operating BCI is possible from researchers to therapists to users and caregivers. Trial registration Registered with NHS GG&C on December 6th 2017; clinicaltrials.gov reference number NCT03257982, url: <https://clinicaltrials.gov/ct2/show/NCT03257982> .

Access or request item here: <https://libkey.io/10.1186/s12984-021-00838-y>

**Clinical Benefits and System Design of FES-Rowing Exercise for Rehabilitation of Individuals with Spinal Cord Injury: A Systematic Review.**

**Authors:** Ye G.;Grabke E.P.;Pakosh M.;Furlan J.C. and Masani, K.

**Publication Date:** 2021

**Journal:** Archives of Physical Medicine and Rehabilitation 102(8), pp. 1595–1605

**Abstract:** Objective: To comprehensively and critically appraise the clinical benefits and engineering designs of functional electrical stimulation (FES)-rowing for management of individuals with spinal cord injury (SCI).



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Access or request item here: <https://libkey.io/10.1016/j.apmr.2021.01.075>

## **Use of Electrical Stimulation for People With Spinal Cord Injury: A Survey of Occupational Therapy Practitioners**

**Authors:** Dionne, Timothy P.; Lenker, James A.; Hennessy, Patrick and Sullivan, Jane E.

**Publication Date:** May ,2020

**Journal:** American Journal of Occupational Therapy 74(3), pp. 1–7

**Abstract:** Importance: When working with clients who have experienced spinal cord injury (SCI), occupational therapy practitioners can face challenges in achieving desired results during functional activity when using electrical stimulation (ES) interventions. In an effort to understand current practice, a survey study was conducted. Objective: For people with SCI, ES elicits positive physiological effects; however, no implementation guidelines exist for upper extremity application of ES for this population. Therefore, we surveyed occupational therapy practitioners about their use of ES with clients who have cervical-level SCI. Design: A 33-item, 20-min online survey was used. Participants and Setting: We queried 57 occupational therapy practitioners with active caseloads in regional rehabilitation centers specializing in SCI, both outpatient and inpatient. Results: For clients with SCI, occupational therapy practitioners used ES most often for grasp-and-release, reaching, and grip or pinch activities using a broad range of parameter settings. Among respondents, 43% did not use a specific treatment protocol; 27% used research evidence to guide selection of parameters. Conclusions and Relevance: Findings suggest that ES treatment parameters are not uniformly applied, introducing potential unknown effects on client outcomes and undermining treatment fidelity. What This Article Adds: Our survey of occupational therapy practitioners regarding their practice and use of ES interventions with this population revealed variation in application of ES treatment parameters. Understanding different treatment approaches and justification used when applying ES to clients with SCI is an important first step in unifying and promoting best practice and maximizing patient outcomes.

Access or request item here: <https://libkey.io/10.5014/ajot.2020.035584>

## **Selective neural electrical stimulation restores hand and forearm movements in individuals with complete tetraplegia**

**Authors:** Tigr, Wafa; Dali, Mélissa; William, Lucie; Fattal, Charles; Gélis, Anthony; Divoux, Jean-Louis; Coulet, Bertrand; Teissier, Jacques; Guiraud, David and Azevedo Coste, Christine

**Publication Date:** 2020

**Journal:** Journal of NeuroEngineering & Rehabilitation (JNER) 17(1), pp. 1–12

**Abstract:** Background: We hypothesized that a selective neural electrical stimulation of radial and median nerves enables the activation of functional movements in the paralyzed hand of individuals with tetraplegia. Compared to previous approaches for which up to 12 muscles were targeted through individual muscular stimulations, we focused on minimizing the number of implanted electrodes however providing almost all the needed and useful hand movements for subjects with complete tetraplegia. Methods: We performed acute experiments during scheduled surgeries of the upper limb with eligible subjects. We scanned a set of multicontact neural stimulation cuff electrode configurations, pre-computed through modeling simulations. We reported the obtained isolated and functional movements that were considered useful for the subject (different grasping movements). Results: In eight subjects, we demonstrated that selective stimulation based on multicontact cuff electrodes



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and optimized current spreading over the active contacts provided isolated, compound, functional and strong movements; most importantly 3 out of 4 had isolated fingers or thumb flexion, one patient performed a Key Grip, another one the Power and Hook Grips, and the 2 last all the 3 Grips. Several configurations were needed to target different areas within the nerve to obtain all the envisioned movements. We further confirmed that the upper limb nerves have muscle specific fascicles, which makes it possible to activate isolated movements. Conclusions: The future goal is to provide patients with functional restoration of object grasping and releasing with a minimally invasive solution: only two cuff electrodes above the elbow. Ethics Committee / ANSM clearance prior to the beginning of the study (inclusion period 2016-2018): CPP Sud Méditerranée, #ID-RCB:2014-A01752-45, first acceptance 10th of February 2015, amended 12th of January 2016. Trial Registration: ([www.clinicaltrials.gov](http://www.clinicaltrials.gov)): #NCT03721861, Retrospectively registered on 26th of October 2018.

**Access or request item here:** <https://libkey.io/10.1186/s12984-020-00676-4>

### **Functional Electrical Stimulation Therapy for Retraining Reaching and Grasping After Spinal Cord Injury and Stroke**

**Authors:** Kapadia N.; Moineau B. and Popovic, M. R.

**Publication Date:** 2020

**Journal:** Frontiers in Neuroscience 14(pagination), pp. Article Number: 718. Date of Publication: 09 Jul 2020

**Abstract:** Neurological conditions like hemiplegia following stroke or tetraplegia following spinal cord injury, result in a massive compromise in motor function. Each of the two conditions can leave individuals dependent on caregivers for the rest of their lives. Once medically stable, rehabilitation is the main stay of treatment. This article will address rehabilitation of upper extremity function. It is long known that moving the affected limb is crucial to recovery following any kind of injury. Overtime, it has also been established that just moving the affected extremities does not suffice, and that the movements have to involve patient's participation, be as close to physiologic movements as possible, and should ideally stimulate the entire neuromuscular circuitry involved in producing the desired movement. For over four decades now, functional electrical stimulation (FES) is being used to either replace or retrain function. The FES therapy discussed in this article has been used to retrain upper extremity function for over 15 years. Published data of pilot studies and randomized control trials show that FES therapy produces significant changes in arm and hand function. There are specific principles of the FES therapy as applied in our studies: (i) stimulation is applied using surface stimulation electrodes, (ii) there is minimum to virtually no pain during application, (iii) each session lasts no more than 45-60 min, (iv) the technology is quite robust and can make up for specificity to a certain extent, and (v) fine motor function like two finger precision grip can be trained (i.e., thumb and index finger tip to tip pinch). The FES therapy protocols can be successfully applied to individuals with paralysis resulting from stroke or spinal cord injury. © Copyright © 2020 Kapadia, Moineau and Popovic.

**Access or request item here:** <https://libkey.io/10.3389/fnins.2020.00718>

### **Clinically Significant Gains in Skillful Grasp Coordination by an Individual With Tetraplegia Using an Implanted Brain-Computer Interface With Forearm Transcutaneous Muscle Stimulation**

**Authors:** Bockbrader, Marcie; Annetta, Nicholas; Friedenber, David; Schwemmer,



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Michael;Skomrock, Nicholas;Colachis IV, Samuel;Zhang, Mingming;Bouton, Chad;Rezai, Ali;Sharma, Gaurav and Mysiw, Walter J.

**Publication Date:** 2019

**Journal:** Archives of Physical Medicine & Rehabilitation 100(7), pp. 1201–1217

**Abstract:** To demonstrate naturalistic motor control speed, coordinated grasp, and carryover from trained to novel objects by an individual with tetraplegia using a brain-computer interface (BCI)-controlled neuroprosthetic. Phase I trial for an intracortical BCI integrated with forearm functional electrical stimulation (FES). Data reported span postimplant days 137 to 1478. Tertiary care outpatient rehabilitation center. A 27-year-old man with C5 class A (on the American Spinal Injury Association Impairment Scale) traumatic spinal cord injury After array implantation in his left (dominant) motor cortex, the participant trained with BCI-FES to control dynamic, coordinated forearm, wrist, and hand movements. Performance on standardized tests of arm motor ability (Graded Redefined Assessment of Strength, Sensibility, and Prehension GRASSP], Action Research Arm Test ARAT], Grasp and Release Test GRT], Box and Block Test), grip myometry, and functional activity measures (Capabilities of Upper Extremity Test CUE-T], Quadriplegia Index of Function-Short Form QIF-SF], Spinal Cord Independence Measure–Self-Report SCIM-SR]) with and without the BCI-FES. With BCI-FES, scores improved from baseline on the following: Grip force (2.9 kg); ARAT cup, cylinders, ball, bar, and blocks; GRT can, fork, peg, weight, and tape; GRASSP strength and prehension (unscrewing lids, pouring from a bottle, transferring pegs); and CUE-T wrist and hand skills. QIF-SF and SCIM-SR eating, grooming, and toileting activities were expected to improve with home use of BCI-FES. Pincer grips and mobility were unaffected. BCI-FES grip skills enabled the participant to play an adapted "Battleship" game and manipulate household objects. Using BCI-FES, the participant performed skillful and coordinated grasps and made clinically significant gains in tests of upper limb function. Practice generalized from training objects to household items and leisure activities. Motor ability improved for palmar, lateral, and tip-to-tip grips. The expects eventual home use to confer greater independence for activities of daily living, consistent with observed neurologic level gains from C5-6 to C7-T1. This marks a critical translational step toward clinical viability for BCI neuroprosthetics. • A man with paralysis regained hand grasp through BCI-controlled arm muscle stimulation. • The device enabled the patient to twist and pour using lateral, palmar, and tip-to-tip grips. • Grips for training objects carried over successfully to novel objects and tasks. • The patient's functional motor level improved when using the BCI from C5-6 to C7-T1. • Translation to home use could decrease dependence for activities of daily living.

**Access or request item here:** <https://libkey.io/10.1016/j.apmr.2018.07.445>

## Case Reports:

**Combining transcranial direct current stimulation and peripheral electrical stimulation to improve upper limb function in a patient with acute central cord syndrome: a case report.**

**Authors:** Matsuo H.;Kubota M.;Hori Y.;Izubuchi Y.;Takahashi A.;Watanabe S.;Nakajima H. and Matsumine, A.



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**Publication Date:** 2022

**Journal:** Journal of International Medical Research 50(3) (pagination), pp. Date of Publication: 01 Mar 2022

**Abstract:** We report the immediate improvement of weakened muscles after combined treatment with transcranial direct current stimulation (tDCS) and peripheral electrical stimulation (PES) in a patient with acute central cord syndrome (CCS) who presented with severe upper limb motor dysfunction. A 70-year-old man sustained CCS with severe motor deficits in the left upper limb, which did not improve with conventional training until 6 days after injury. On the seventh day after the injury, the left upper limb was targeted with combined tDCS (1 mA for 20 minutes/day, anode on the right, cathode on the left) and PES (deltoid and wrist extensors, 20 minutes/day at the motor threshold), and his performance score immediately improved from 0 to 6 on the Box and Block test. After four sessions, the left upper limb function improved to 32 on the Box and Block test, and manual muscle test scores of the stimulated deltoid and wrist extensors improved from 1 to 2. This improvement of the left upper limb led to improved self-care activities such as eating and changing clothes. Exercise combined with tDCS and PES may be a novel treatment for upper limb movement deficits after acute CCS.

**Access or request item here:** <https://libkey.io/10.1177/03000605221083248>

### **Cortical Re-organization After Traumatic Brain Injury Elicited Using Functional Electrical Stimulation Therapy: A Case Report.**

**Authors:** Milosevic M.;Nakanishi T.;Sasaki A.;Yamaguchi A.;Nomura T.;Popovic M.R. and Nakazawa, K.

**Publication Date:** 2021

**Journal:** Frontiers in Neuroscience 15(pagination), pp. Article Number: 693861. Date of Publication: 19 Aug 2021

**Abstract:** Functional electrical stimulation therapy (FEST) can improve motor function after neurological injuries. However, little is known about cortical changes after FEST and whether it can improve motor function after traumatic brain injury (TBI). Our study examined cortical changes and motor improvements in one male participant with chronic TBI suffering from mild motor impairment affecting the right upper-limb during 3-months of FEST and during 3-months follow-up. In total, 36 sessions of FEST were applied to enable upper-limb grasping and reaching movements. Short-term assessments carried out using transcranial magnetic stimulation (TMS) showed reduced cortical silent period (CSP), indicating cortical and/or subcortical inhibition after each intervention. At the same time, no changes in motor evoked potentials (MEPs) were observed. Long-term assessments showed increased MEP corticospinal excitability after 12-weeks of FEST, which seemed to remain during both follow-ups, while no changes in CSP were observed. Similarly, long-term assessments using TMS mapping showed larger hand MEP area in the primary motor cortex (M1) after 12-weeks of FEST as well as during both follow-ups. Corroborating TMS results, functional magnetic resonance imaging (fMRI) data showed M1 activations increased during hand grip and finger pinch tasks after 12-weeks of FEST, while gradual reduction of activity compared to after the intervention was seen during follow-ups. Widespread changes were seen not only in the M1, but also sensory, parietal rostroventral, supplementary motor, and premotor areas in both contralateral and ipsilateral hemispheres, especially during the finger pinch task. Drawing test performance showed improvements after the intervention and during follow-ups. Our findings suggest that task-specific and repetitive FEST can effectively increase cortical activations by integrating voluntary motor commands and sensorimotor



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network through functional electrical stimulation (FES). Overall, our results demonstrated cortical re-organization in an individual with chronic TBI after FEST. © Copyright © 2021 Milosevic, Nakanishi, Sasaki, Yamaguchi, Nomura, Popovic and Nakazawa.

**Access or request item here:** <https://libkey.io/10.3389/fnins.2021.693861>

## Conference Proceedings:

### **Functional electrical stimulation for improving upper limb function following spinal cord injuries**

**Authors:** Bucys H., Gordon H. and Killingback, C.

**Publication Date:** 2025

**Publication Details:** Physiotherapy (United Kingdom). Conference: CSP Annual Conference 2024. Imperial College London Conference Center, London United Kingdom. 126(Supplement 1) (no pagination); Elsevier Ltd,

**Abstract:** Purpose: Spinal Cord Injuries (SCIs) are life-changing, with over 50% affecting upper limb function. Loss of upper limb function can significantly affect independence and quality of life, and restoration is a high priority for many. Functional Electrical Stimulation (FES) uses electrical impulses to excite damaged neurons, with varying research regarding its effectiveness for improving upper limb function following SCI. This literature review investigates whether FES is effective for improving upper limb function following SCI.

**Access or request item here:** <https://libkey.io/10.1016/j.physio.2025.101650>

### **Prediction of Muscle Response to FES Therapy after Cervical Spinal Cord Injuries Using Surface Electromyography**

**Authors:** Li G., Balbinot G., KalsiRyan S. and Zariffa, J.

**Publication Date:** 2021

**Publication Details:** Journal of Spinal Cord Medicine. Conference: 9th National Spinal Cord Injury Conference. Virtual. 44(SUPPL 1) (pp S316); Taylor and Francis Ltd.,

**Abstract:** Background: Cervical spinal cord injuries (SCI) can severely impair the upper limbs, whose recovery has been reported to be the top priority. Functional electrical stimulation (FES) has been used to produce contractions in paretic muscles after cervical SCI and has demonstrated promising results in improving upper limb functions when utilized in therapy. However, muscles respond inconsistently, and the responsiveness is currently unpredictable. To maximize patient outcomes and reduce barriers to access, making best use of the limited therapy time available is of vital importance.

**Access or request item here:** <https://libkey.io/10.1080/10790268.2021.1957653>

### **Predicting functional force production capabilities of upper extremity functional electrical stimulation neuroprostheses: A proof of concept study**

**Authors:** Schearer E.M. and Wolf, D.N.

**Publication Date:** 2020

**Publication Details:** United Kingdom: Institute of Physics Publishing (E-



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**Abstract:** Objective. This study's goal was to demonstrate person-specific predictions of the force production capabilities of a paralyzed arm when actuated with a functional electrical stimulation (FES) neuroprosthesis. These predictions allow us to determine, for each hand position in a person's workspace, if FES activated muscles can produce enough force to hold the arm against gravity and other passive forces, the amount of force the arm can potentially exert on external objects, and in which directions FES can move the arm. Approach. We computed force production predictions for a person with high tetraplegia and an FES neuroprosthesis used to activate muscles in her shoulder and arm. We developed Gaussian process regression models of the force produced at the end of the forearm when stimulating individual muscles at different wrist positions in the person's workspace. For any given wrist position, we predicted all possible forces a person can produce by any combination of individual muscles. Based on the force predictions, we determined if FES could produce force sufficient to overcome passive forces to hold a wrist position, the maximum force FES could produce in all directions, and the set of directions in which FES could move the arm. To estimate the error in our predictions, we then compared our force predictions based on single-muscle models to the actual forces produced when stimulating combinations of the person's muscles. Main results. Our models classified the person's ability to hold static arm positions correctly for 83% (Session #1) and 69% (Session #2) for 39 wrist positions over two sessions. We predicted this person's ability to produce force at the end of her arm with an RMS error of 5.5 N and the percent of directions for which FES could achieve motion with RMS error of 10%. The accuracy of these predictions is similar to that found in the literature for FES systems with fewer degrees of freedom and fewer muscles. Significance. These person and device-specific predictions of functional capabilities of the arm allow neuroprosthesis developers to set achievable functional objectives for the systems they develop. These predictions can potentially serve as a screening tool for clinicians to use in planning neuroprosthetic interventions, greatly reducing the risk and uncertainty in such interventions.

**Access or request item here:** <https://libkey.io/10.1088/1741-2552/ab68b3>

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DATABASES AND INFORMATION SOURCES USED					
✓	Pubmed		HMIC		BMJ Best Practice
	Medline		Social Policy and Practice		Cochrane Library
✓	Emcare	✓	CINAHL		TRIP
✓	Embase		PsycINFO		Grey Literature
	AMED		UpToDate		Other



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### PURPOSE OF SEARCH

	Patient info/health & well being	✓	Clinical decision making (inc. patient care)
	Executive Team support		Research/Education/Professional development
	Quality Improvement		Primary Care & Neighbourhoods Directorate support
	KM/Management decision making	✓	Other

### USER CATEGORY OF REQUESTOR

	Medical students		Patients/public
	Nursing/midwifery students		Physician Associates
	Doctor/Psychiatrist		Public Health (Somerset CC)
	Nurses/Midwives		Other
✓	Allied Health professionals		

### HAS PERMISSION TO SHARE THE RESULTS BEEN OBTAINED FROM THE REQUESTOR?

✓	YES - share		NO – do not share
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### KEY WORDS/SEARCH STRATEGY INCLUDING MESH HEADINGS

### LIMITS USED

<p>"neuromuscular electrical stimulation" OR "NMES" OR "functional electrical stimulation" OR "FES" OR "electrical stimulation" ) AND "upper limb" OR "upper extremity" OR "arm" OR "hand" OR "wrist" OR "elbow" AND "multiple sclerosis" or "ms" or "multiple-sclerosis" or "parkinson* disease" or "pd" or "brain injury" OR "acquired brain injury" OR "traumatic brain injury" OR "spinal cord injury" OR "SCI" OR "neurodegenerative disease**"</p>	Last 5 years
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