The Influence of Functional Electrical Stimulation (FES) Cycling on Spasticity in Adolescents with Spinal Cord Injury

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CLINICAL SCENARIO: Spasticity is a significant complication for individuals with spinal cord injury. High spasticity may lead to limits in functional mobility and self-care skills, decreased range of motion, increased risk for joint contracture and skin breakdown, and decreased safety. Frequently, oral medication alone is insufficient in amelioration of spasticity and these resulting issues, in turn worsening the impact of the disability. These complications can lead to costly medical interventions and decreased quality of life. Focal management with botulinum toxin injections (such as Botox) has been demonstrated to be efficacious, but there are few non-medical interventions for the treatment of spasticity. Low load, long duration bracing has demonstrated some value, but is not always practical or a long-term solution. Functional Electrical Stimulation (FES) cycling is an emerging area of treatment to reduce spasticity and its resulting complications, but evidence is limited.

FOCUSED CLINICAL QUESTION: For children between the ages of 5 to 15 years with AIS classifications A, B, or C, how does the use of FES cycling compare with no FES cycling on spasticity intensity and frequency?

CLINICAL BOTTOM LINE:

- FES cycling improves spasticity associated with neurological insult.
- Frequency of cycling, FES parameters, and duration of amelioration require additional investigation.
- The evidence is stronger in adults than it is in pediatrics for FES cycling, but no contraindications for its use in pediatrics are identified in the adult literature.

SUMMARY of Search, ‘Best’ Evidence appraised, and Key Findings: 4 articles met inclusion criteria and helped answer the clinical question best:

- FES cycling yielded greater decreases in spasticity as compared to passive cycling in adults with AIS A SCI.

- Patients with AIS B, C, or D SCI demonstrated decreased spasticity following FES cycling.

- Spasticity-decreasing effects were observed following middle frequency alternating current
in stimulation-propelled cycling in adult patients with chronic AIS A SCI.


- Spasticity decreased and functional skills increased in a patient with spastic diplegic CP following a home-based NMES program, including unilateral stimulation to the quadriceps every other day for six weeks. Spasticity increased during the treatment period in the untrained leg

Limitation of this CAT: Relevant research was limited, especially articles involving a randomized control in the pediatric SCI population. Selected articles represent a low level of evidence, given their limited sample size. This critically appraised topic has not been peer-reviewed by another independent person.

SEARCH STRATEGY:
- Patient/Client Group: Children with spinal cord injury, age 5 to 15, AIS A, B, or C
- Intervention (or Assessment): FES cycling
- Comparison: non-FES cycling
- Outcome(s): Spasticity intensity and frequency

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<thead>
<tr>
<th>Databases</th>
<th>Search Terms</th>
<th>Limits used</th>
</tr>
</thead>
<tbody>
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<td>Pub Med</td>
<td>Spinal cord injury, pediatric, children, spasticity, functional electrical stimulation, cycling, ergometry, paraplegia, rehabilitation And all permutations of above</td>
<td>English language Humans</td>
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INCLUSION and EXCLUSION CRITERIA:
- Inclusion: Peer-reviewed literature on the influence of FES interventions (cycling and non-cycling) on spasticity in patients with paralysis (CP and SCI).
- Exclusion: Articles from non-peer reviewed sources or without scientific merit and articles published prior to 1992 were excluded from review. Studies with interventions involving surgical or medical management of spasticity were also excluded.

BEST EVIDENCE

The following study/paper was identified as the ‘best’ evidence and selected for critical appraisal. Reasons for selecting this study were: Krause (2008), Reichenfelser (2012), and Szecsi (2009) represent the strongest evidence for spasticity management in SCI. The work by Daichman (2003) represents the only evidence for FES-derived spasticity management in children.

SUMMARY OF BEST EVIDENCE

**Aim/Objective:** To determine whether functional electrical stimulation (FES) cycling is more effective than passive leg cycling for reduction of muscle tone.

**Design:** Cross-over design

**Setting:** Outpatient clinic in a university hospital

**Participants:** 5 patients with complete paraplegic spinal cord injury (two women, three men) with a mean age of 46 years old.

**Procedures:** Baseline status of muscle tone was assessed using the Modified Ashworth Spasticity Scale (MASS). Each patient participated in one active cycling session with FES and one passive cycling session. There was a week between sessions. The aim was to compare the short lasting effects of the two interventions on spasticity. Spastic muscle tone was assessed in the quadriceps by two investigators, one of which was blinded to the applied session. The results were compared to each other to assess the effectiveness of interventions on spastic muscle tone.

**Outcome Measures:** Spastic muscle tone was measured using the MASS and by pendulum testing of spasticity. The MASS was completed five times and the values were averaged. Ten pendulum tests were completed with each leg and the results were averaged.

**Results:** MASS is significantly reduced after completion of both interventions, passive and with FES; however there was a greater reduction with use of FES. The relaxation index increased by 68% with use of FES cycling. The increase after passive movement was smaller, around 12%.

**Conclusion:** Clinical use of FES yields greater reduction of spasticity than passive movement alone. FES also yields other physiological benefits including increase in bone density and muscle force.

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**Monitoring of Spasticity and Functional Ability in Individuals with Incomplete Spinal Cord Injury with a Functional Electrical Stimulation Cycling System** (Reichenfelser et al., 2012)

**Aim/Objective:** To monitor spasticity and functional abilities in adults with incomplete spinal cord injury in conjunction with functional electrical stimulation ergometry.

**Design:** Stratified, repeated measures

**Setting:** Outpatient Rehabilitation Center

**Participants:** 26 adults with C4-L1, AIS B-D SCI greater than nine months were compared to 13 able-bodied individuals.

**Procedures:** The participants were divided into three groups as follows: Group A included 8 individuals with SCI and mean MAS >1, Group B included 15 individuals with SCI and mean MAS <1, and group C included 13 able-bodied individuals. Each group completed training sessions three times per week for an average period of two months. There were three phases including pre-training, training, and post-training. The pre-training and the post-training included a spasticity assessment according to the Modified Ashworth Scale (MAS). The training period included cycling with use of FES.

**Outcome Measures:** The mean decrease in passive resistance due to FES cycling training was calculated and compared among groups.

**Results:** The spastic group A showed the greatest reduction in resistance after the FES training, which was particularly evident with increased speeds. Groups B and C show similar results but the values were less significant than the spastic group A.

**Conclusion:** Spasticity is reduced following FES cycling training. The relaxation increases with increased velocity.

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**FES-propelled Cycling of SCI Subjects with Highly Spastic Leg Musculature.** (Szecsi & Schiller, 2009)

**Aim/Objective:** To compare the effects of two waveforms [low frequency rectangular pulse (LFRP) and middle frequency alternating current (MFAC)] used in cycling on the muscles of highly spastic patients with SCI.

**Design:** Cross-over design

**Setting:** Research center
Participants: 13 adults with C7-T12 AIS A Chronic SCI and Modified Ashworth Scale (MAS) scores >2 in the quadriceps and hamstrings.

Procedures: Each participant underwent three session over two weeks: 1. isometric torque generation using LFRP (rectangular, biphasic, charged balanced pulses with a frequency of 20Hz, maximum pulse amplitude of 127mA, and constant pulse width of 500µs) and MFAC (4KHz sinusoidal modulated with 50Hz on-off rectangles and duty cycle of 1:1) stimulation, 2. ergometry using LFRP stimulation, and 3. ergometry using MFAC stimulation. Amplitudes were adjusted to patient tolerance and/or tetany. The order of sessions was randomized.

Outcome Measures: Isometric torque generated by stimulation (measure of spastic reaction) and the power output of stimulation-induced cycling (primarily measured by cadence, indicating fluidity of movement). MAS measurements were recorded before and after each session.

Results: Larger isometric responses were observed in response to LFRP as compared to MFAC stimulation. More unintentional stops occurred during LFRP and more work, or power, was produced under the MFAC condition. A significant decrease in MAS measurements was observed after both stimulation sessions, however, MAS measurements revealed no significant spasticity difference between the MFAC and LFRP condition.

Conclusion: FES-propelled cycling decreased the spasticity effects in quadricep and hamstring muscles of patient with chronic AIS A SCI, with a carryover effect of 1 hour to 1.5 days. MFAC stimulation is superior to LFRP stimulation when targeting the spastic muscles.

The Effects of a NMES Home Program on Impairments and Functional Skills of a Child with Spastic Diplegic Cerebral Palsy: A Case Report. (Daichman et al., 2003)

Aim/Objective: To evaluate the effect of NMES-assisted LE strengthening on the strength, spasticity, and function of the lower extremity (LE) of a patient with spastic diplegic CP.

Design: Single case study, within subject control (only one LE was stimulated)

Setting: Home-based intervention, Hospital-based training

Participants: 13-year old female with spastic diplegic CP, who walked with posterior walker, (B) AFO, and weak quadriceps

Procedures: Pretest, followed by six-weeks of intervention and post-testing. The right LE was randomly selected to receive the intervention. Three sets of 10 repetitions of NMES-assisted knee extension were performed every other day. Parameters were selected to achieve tetany and protect against fatigue: 35 Hz, 300µs, 10s on, 50s off with 2s ramp.

Outcome Measures: Quadriceps muscle strength using a handheld dynamometer, hamstring spasticity using the MAS and KinCom dynamometer, spatiotemporal parameters of gait using the GAITRite, and functional motor skills using the Pediatric Evaluation of Disability Inventory (PEDI)

Results: On the right side, quadriceps strength increased, via both dynamometry and manual muscle test (MMT), and the popliteal angle decreased. On the left side, strength was unchanged and the popliteal angle decreased. Via the KinCom, the resistance of the right hamstring decreased at 3 higher velocities, indicating improved spasticity. The resistance of the left hamstring increased at all velocities. Improvements were seen in gait temporal spatial parameters: walking velocity, step length, cadence, step time, stance time, base of support, and symmetry. Improvements in the mobility and self care domains of the PEDI were also reported.

Conclusion: NMES-assisted strengthening improves strength and spasticity with commensurate remediation of functional limitations. The author speculates that NMES provides for a stronger contraction over a greater range of motion than the patient was able to achieve on her own, thus providing motor unit activation, motor learning, and potential muscle hypertrophy.

IMPLICATIONS FOR PRACTICE, EDUCATION and FUTURE RESEARCH

Practice:
• FES cycling seems to reduce spasticity in a meaningful, practical way for patients with LE spasticity from central nervous system dysfunction. It has the potential to provide patients with a non-medical alternative for spasticity management.
• More frequent FES cycling is associated with greater decreases in spasticity and longer lasting effects. No ceiling effects or risks were investigated. Recommendations should fall in line with general exercise guidelines.

Education:
• Therapists and physiatrists should be educated in the prescription of FES cycling and its parameters including:
  o FES parameters (pulse width, frequency) and their effects on muscle
  o Frequency and duration of cycling
  o Integration and progression of speed and resistance to encourage hypertrophy
• Therapists and patients/caregivers should be educated on the safe application of FES, with and without cycling.

Research:
• More pediatric SCI research is required to provide conclusive evidence.
• More evidence is needed to assess effective dosing, appropriate stimulation frequencies, and carryover effects of FES cycling.
• Study the effects of weight bearing, with and without FES, as compared to the effects of FES cycling on spasticity