FES Cycle Ergometry for Stroke and Brain Injury – Evidence Library

Contents

Intensive training of subjects with chronic hemiparesis on a motorized cycle combined with functional electrical stimulation (FES): a feasibility and safety study.

Alon G.; Conroy V.M.; Donner T.W. (2010).
Physiotherapy Research International, 16(2): 81-91.

Abstract

Background and Purpose. This study tested the safety and ability of subjects with chronic hemiplegia to tolerate intensive training using a motorized cycle combined with functional electrical stimulation (FES) system.

Methods. A case series of 10 subjects with chronic stroke participated in 30-minute three times per week cycling on a stationary motorized cycling system combined with FES (RT300TM). The stimulation activated the dorsal and plantar flexors, the quadriceps and the hamstrings using four channels and a stimulation pattern that assisted cycling motion of the paretic lower limb. Patients were instructed to cycle as close as possible to 60 rpm and the resistance to cycling was gradually increased using a computer-based algorism. The training lasted eight weeks.

Results. All 10 participants completed the training without adverse reactions to the training or the FES. The kcal utilized during the training increased significantly ($p = 0.0003$) between session 1 (2.2 ± 0.47), session 12 (4.3 ± 1.2) and session 24 (7.5 ± 1.8). Peak pedaling power increased from 6.5 ± 0.5 W pre-training to 18.0 ± 5.4 W post-training. Locomotion variables that improved significantly were time to complete the get up and go test (45.4 ± 54.9 seconds vs. 34.0 ± 31.8 seconds) a 24.6% improvement ($p = 0.03$) and gait velocity, which increased 25.0% from 0.4 ± 0.3 m/sec to 0.5 ± 0.4 m/sec ($p = 0.01$).

Conclusion. Using a motorized cycle combined with FES intensive training appears safe and can be tolerated by patients with chronic stroke of wide age range, diverse severity of cardio-pulmonary deconditioning, motor loss and locomotor deficits.

Cycling induced by electrical stimulation improves activation and symmetry during pedaling in hemiparetic patients.

Ambrosini E.; Ferrante S.; Ferrigno G.; Molteni F.; Pedrocchi A. (2012).
Neural Systems and Rehabilitation Engineering, IEEE Transactions on, 20(3): 320-330.

Abstract

A randomized controlled trial, involving 35 post-acute hemiparetic patients, demonstrated that a four-week treatment of cycling induced by functional electrical stimulation (FES-cycling) promotes motor recovery. Analyzing additional data acquired during that study, the present work investigated whether these improvements were associated to changes in muscle strength and motor coordination. Participants were randomized to receive FES-cycling or placebo FES-cycling. Clinical outcome measures were: the Motricity Index (MI), the gait speed, the electromyography activation of the rectus femoris and biceps femoris, and the mechanical work produced by each leg during voluntary pedaling. To provide a comparison with normal values, healthy adults also carried out the pedaling test. Patients were evaluated before, after training, and at follow-up visits. A significant treatment effect in favor of FES-treated patients was found in terms of MI scores and unbalance in mechanical works, while differences in gait speed were not significant (ANCOVA). Significant improvements in the activation of the paretic muscles were highlighted in the FES group, while no significant change was found in the placebo group (Friedman test). Our findings suggested that improvements in motor functions induced by FES-cycling training were associated with a more symmetrical involvement of the two legs and an improved motor coordination.

Cycling induced by electrical stimulation improves motor recovery in post acute hemiparetic patients: a randomized controlled trial.

Ambrosini E.; Ferrante S.; Pedrocchi A.; Ferrigno G.; Molteni F. (2011).

Stroke, 42: 1068-1073.

Abstract

Background and Purpose—This study assessed whether cycling induced by functional electrical stimulation (FES) was more effective than passive cycling with placebo stimulation in promoting motor recovery and walking ability in postacute hemiparetic patients.

Methods—In a double-blind, randomized, controlled trial, 35 patients were included and randomized to receive FES-induced cycling training or placebo FES cycling. The 4-week treatment consisted of 20 sessions lasting 25 minutes each. Primary outcome measures included the leg subscale of the Motricity Index and gait speed during a 50-meter walking test. Secondary outcomes were the Trunk Control Test, the Upright Motor Control Test, the mean work produced by the paretic leg, and the unbalance in mechanical work between paretic and nonparetic legs during voluntary pedaling. Participants were evaluated before training, after training, and at 3- to 5-month follow-up visits.

Results—No significant differences were found between groups at baseline. Repeated-measures ANOVA ($P<0.05$) revealed significant increases in Motricity Index, Trunk Control Test, Upright Motor Control Test, gait speed, and mean work of the paretic leg after training and at follow-up assessments for FES-treated patients. No outcome measures demonstrated significant improvements after training in the placebo group. Both groups showed no significant differences between assessments after training and at follow-up. A main effect favoring FES-treated patients was demonstrated by repeated-measures ANCOVA for Motricity Index ($P<0.001$), Trunk Control Test ($P=0.001$), Upright Motor Control Test ($P=0.005$), and pedaling unbalance ($P=0.038$).

Conclusions—The study demonstrated that 20 sessions of FES cycling training significantly improved lower extremity motor functions and accelerated the recovery of overground locomotion in postacute hemiparetic patients. Improvements were maintained at follow-up.

Functional electrical stimulation does not improve mobility in people with acquired brain injury and its effects on strength are unclear: a randomised trial.

De Sousa, D.G., Harvey, L.A., Dorsch, S., Leung, J. & Harris, W. (2016).

Journal of Physiotherapy, 62: 203-208

Abstract

Question: Does 4 weeks of active functional electrical stimulation (FES) cycling in addition to usual care improve mobility and strength more than usual care alone in people with a sub-acute acquired brain injury caused by stroke or trauma?

Design: Multi centre, randomised, controlled trial.

Participants: Forty patients from three Sydney hospitals with recently acquired brain injury and a mean composite strength score in the affected lower limb of 7 (SD 5) out of 20 points.

Intervention: Participants in the experimental group received an incremental, progressive, FES cycling program five times a week over a 4-week period. All participants received usual care.

Outcome measures: Outcome measures were taken at baseline and at 4 weeks. Primary outcomes were mobility and strength of the knee extensors of the affected lower limb. Mobility was measured with three mobility items of the Functional Independence Measure and strength was measured with a hand-held dynamometer. Secondary outcomes were strength of the knee extensors of the unaffected lower limb, strength of key muscles of the affected lower limb and spasticity of the affected plantar flexors.

Results: All but one participant completed the study. The mean between-group differences for mobility and strength of the knee

extensors of the affected lower limb were –0.3/21 points (95% CI –3.2 to 2.7) and 7.5 Nm (95% CI –5.1 to 20.2), where positive values favoured the experimental group. The only secondary outcome that suggested a possible treatment effect was strength of key muscles of the affected lower limb with a mean between-group difference of 3.0/20 points (95% CI 1.3 to 4.8).

Conclusion: Functional electrical stimulation cycling does not improve mobility in people with acquired brain injury and its effects on strength are unclear.

Cycling induced by functional electrical stimulation improves the muscular strength and the motor control of individuals with post-acute stroke.

Ferrante S.; Pedrocchi A.; Ferrigno G.; Molteni F. (2008)

Europa Medicophysica-SIMFER 2007 Award Winner. *European Journal of Physical and Rehabilitation Medicine*, 44: 159-167.

Abstract

AIM: The aim of this study was to investigate the effectiveness of cycling induced by functional electrical stimulation (FES) in patients with postacute stroke.

METHODS: Twenty postacute inpatients were recruited and were randomly shared in a control group (56+/-9.2 years old, 50.8+/-24.5 days post-stroke) performing the standard rehabilitation (SR) and a FES group (51+/-12 years old, 56.1+/-22.8 days post-stroke) performing FES cycling in addition to SR. Both the groups performed 3 hours of rehabilitation per day for 4 weeks. The FES cycling was applied daily for 35 minutes and quadriceps, hamstring, gluteus maximus and tibialis anterior of both the legs were stimulated. The two groups were compared by the following outcome measurements before and after treatment: maximum isometric voluntary contraction (MVC) of quadriceps, walking and sit-to-stand ability, motricity index, upright motor control test and trunk control test.
RESULTS: After the treatment, the U-Mann-Whitney test demonstrated that the FES group produced a significantly higher increase of the muscular force produced by both the quadriceps during MVC with respect to the control group ($P<0.05$). Seventy percent of FES patients learned how to perform the sit to stand movement with three different rising speeds while no control patients develop the ability to perform the task properly.

CONCLUSION: Rehabilitation including FES cycling was more effective in promoting muscle strength and motor recovery of the lower extremity than therapist-assisted SR alone. Tests on an enlarged number of patients are necessary for generalization before proposing FES cycling in the clinical rehabilitation of post-acute stroke patients.

Effects of electric stimulation-assisted cycling training in people with chronic stroke.

Janssen T.W.; Beltman J.M.; Elich P.; Koppe P.A.; Konijnenbelt H.; de Haan A.; Gerrits K.H. (2008).

Archive of Physical Medicine and Rehabilitation, 89(3): 463-469.

Abstract

Objective: To evaluate whether leg cycling training in subjects with chronic stroke can improve cycling performance, aerobic capacity, muscle strength, and functional performance and to determine if electric stimulation (ES) to the contralateral (paretic) leg during cycling has additional effects over cycling without ES.

Design: A randomized controlled trial, with a partial double-blind design.

Setting: A rehabilitation center.

Participants: Twelve stroke patients (range, 18–70y), more than 5 months poststroke, with lower-extremity hemiparesis.

Intervention: Subjects were randomly assigned to groups that performed cycling exercise, one with ES evoking muscle contractions and a control group with ES not evoking muscle contractions. Subjects, blinded for group assignment, trained twice a week for 6 weeks.

Main Outcome Measures: Changes in aerobic capacity and maximal power output,

functional performance, and lower-limb muscle strength.

Results: Aerobic capacity and maximal power output significantly increased by 13.8%±19.1% and 38.1%±19.8%, but muscle strength was not significantly enhanced after training. Functional performance improved (ie, scores on the Berg Balance Scale increased by 6.9%±5.8% (P=.000) and the six-minute walk test improved by 14.5%±14.1% (P=.035). There was no significant effect on the Rivermead Mobility Index (P=.165). Training-induced changes were not significantly different between the 2 groups. Changes in cycling performance and aerobic capacity were not significantly related to changes in functional performance.

Conclusions: This study showed that a short cycling training program on a semirecumbent cycle ergometer can markedly improve cycling performance, aerobic capacity, and functional performance of people with chronic stroke. The use of ES had no additional effects in this specific group of subjects with chronic stroke.

The effects of assisted ergometer training with a functional electrical stimulation on exercise capacity and functional ability in subacute stroke patients.

Lee S.Y.; Kang S.Y.; Im S.H.; Kim B.R.; Kim S.M.; Yoon H.M.; Han E.Y. (2013).

Annals of Rehabilitation Medicine, 37(5): 619-627.

Abstract

Objective: To determine if assistive ergometer training can improve the functional ability and aerobic capacity of subacute stroke patients and if functional electrical stimulation (FES) of the paretic leg during ergometer cycling has additional effects.
Methods: Sixteen subacute stroke patents were randomly assigned to the FES group (n=8) or the control group (n=8). All patients underwent assistive ergometer training for 30 minutes (five times per week for 4 weeks). The electrical stimulation group received FES of the paretic lower limb muscles during assistive ergometer training. The six-minute walk test (6MWT), Berg Balance Scale (BBS), and the Korean version of Modified Barthel Index (K-MBI) were evaluated at the beginning and end of treatment. Peak oxygen consumption (Vo2peak), metabolic equivalent (MET), resting and maximal heart rate, resting and maximal blood pressure, maximal rate pressure product, submaximal rate pressure product, submaximal rate of perceived exertion, exercise duration, respiratory exchange ratio, and estimated anaerobic threshold (AT) were determined with the exercise tolerance test before and after treatment.
Results: At 4 weeks after treatment, the FES assistive ergometer training group showed significant improvements in 6MWT (p=0.01), BBS (p=0.01), K-MBI (p=0.01), Vo2peak (p=0.02), MET (p=0.02), and estimated AT (p=0.02). The control group showed improvements in only BBS (p=0.01) and K-MBI (p=0.02). However, there was no significant difference in exercise capacity and functional ability between the two groups.
Conclusion: This study demonstrated that ergometer training for 4 weeks improved the functional ability of subacute stroke patients. In addition, aerobic capacity was improved after assisted ergometer training with a FES only.

Effects of a functional electrical stimulation-assisted leg-cycling wheelchair on reducing spasticity of patients after stroke.

Lo H.C.; Tsai K.H.; Su F.C.; Chang G.L.; Yeh C.Y. (2009).

Journal of Rehabilitation Medicine, 41(4), 242-246.

Abstract

Objective: To determine whether short-term propulsion of a functional electrical stimulation-assisted leg-cycling wheelchair (FES-LW) in patients with stroke can reduce spasticity of the affected leg and whether FES has additional effects on reducing spasticity.
Design: Within-subject comparison.
Subjects: A total of 17 patients after stroke were recruited from the university hospital.
Methods: Subjects propelled 2 leg-cycling wheelchairs (the FES-LW and the LW) and a manual wheelchair along an oval pathway. The Modified Ashworth Scale (MAS), H reflex/maximal M response (H/M ratio) and relaxation index were used to evaluate the

immediate effects on leg spasticity. The changes in MAS, H/M and relaxation index were used to evaluate the effect of FES in comparing 2 leg-cycling wheelchairs.
Results: The MAS and H/M ratio were significantly decreased and the relaxation index significantly increased by FES-LW and LW usage. For subjects with higher muscle tone, significant lowering of the changes in MAS, H/M ratio and higher relaxation index were found for FES-LW usage compared with LW usage.
Conclusion: Leg spasticity is reduced after short-term propulsion of the FES-LW and LW. The application of FES has an additional effect on reducing spasticity in subjects with higher muscle tone.

Cycling exercise with functional electrical stimulation improves postural control in stroke patients.

Lo H.C.; Tsai K.H.; Su F.C.; Chang G.L.Yeh C.Y. (2012).
Gait & Posture, 35(3): 506-510.

Abstract

The aim of this study is to determine whether short term functional electrical stimulation (FES)-assisted cycling training can affect the postural control of stroke patients, and whether the application of FES can enhance the effect of cycling training. 20 stroke patients were randomly assigned to the FES-cycling group (FES-CG) or the cycling group (CG). Measurements were completed before and immediately after each 20 min training sessions. The measurements included a balance test (to quantify the postural control ability), a Hoffmann's reflex/motor response ratio (H/M ratio) test and a pendulum test (to quantify the muscle tone). In the balance test, some parameters in all directions exhibited significant intervention effects between the FES-CG group and the CG group. The H/M ratios (p = .014; .005, FES-CG and CG respectively) and relaxation index (p = .005; .047, FES-CG and CG respectively) revealed significant difference between FES-CG and CG group. The change ratios of directional control in the forward direction and H/M ratio revealed significant difference (p = .022; .015) between FES-CG and CG among subjects with higher muscle tone. The stroke subjects' postural control was improved while their muscle tone was reduced after the 20 min cycling training program both with and without FES. We conclude that cycling training, with or without FES may reduce spasticity in stroke patients. The application of FES in cycling exercise was shown to be more effective in stroke patients with higher muscle tone.

Review: Clinical Benefits of Functional Electrical Stimulation Cycling Exercise for Subjects with Central Neurological Impairments.

Peng, C.-W.; Chen, S.-C.; Lai, C.-H.; Chen, C.-J., Chen, C.-C., Mizrahi, J. & Handa, Y. (2011).
Journal of Medical and Biological Engineering, 31(1): 1-11.

Abstract

Functional electrical stimulation (FES) cycling ergometer has been utilized in recent decades for rehabilitation by sequentially stimulating the large leg-actuating muscles of paralyzed leg muscles to produce cyclical leg motion. A number of studies reported physiological adaptations after regular FES-cycling exercise (FESCE) training in subjects with spinal cord injury, stroke, cerebral palsy and other conditions. This article provides a comprehensive overview of general aspects of FES cycling systems and clinical applications of FESCE. The studies cited in this article provide supportive findings for the potential clinical efficacy of FESCE for reducing the risk of secondary medical complications in subjects with paralysis. The potential therapeutic benefits of FESCE include conditioning the cardiopulmonary, muscular, and skeletal systems, and improving other physiological and psychological performances. Our recent pilot study also indicated that the decrease of leg spasticity in subjects with cerebral palsy is one of the acute effects of FESCE. In conclusion, we recommend that FESCE is of benefit in a variety of aspects to improve the general condition and to prevent deterioration in subjects with central neurological impairments.

Functional electrical stimulation assisted cycling of patients with sub acute stroke: kinetic and kinematic analysis.

Szecsi J.; Krewer C.; Muller F.Straube A. (2008).
Clinical Biomechanics, 23(8): 1086-1094.

Abstract

Background: Cycling is a safe and functionally effective exercise for patients with early post-stroke and poor balance. Such exercise is considered even more effective when functional electrical stimulation is added.
Aims: Our principal aim was to determine the biomechanically quantifiable parameters of cycling that can be improved in patients with subacute hemiparesis by incorporating functional electrical stimulation. These parameters were defined as objective goals that can be achieved in clinical applications. A secondary aim was to determine whether they could be used to identify subjects who would benefit from such therapy.
Methods: Using a tricycle testbed, we tested 39 subacute (mean 10.9 weeks post-stroke (SD 5.9)), hemiplegic subjects. During isometric measurements we recorded volitional and electrically evoked crank torques, the latter at maximal tolerable intensity. During ergometric measurements, volitional pedaling was alternated with combined pedaling (volitional supported by stimulation), performed at 30-s intervals. Power, smoothness, and symmetry of cycling were evaluated.
Findings: Twenty-six percent of the subjects significantly improved the smoothness of their cycling with functional electrical stimulation. Only 8% and 10% significantly increased their power and symmetry, respectively. The improvement in smoothness significantly correlated with the capability of the individual to generate electrical torque (Spearman's rank correlation coefficient = 0.66 at P = 0.001).
Interpretation: The smoothness of cycling was the most sensitive parameter improved by functional electrical stimulation. This improvement depended on the amount of torque evoked, and the torque achieved, in turn, correlated with the tolerated intensity of stimulation.

Effect of a bout of leg cycling with electrical stimulation on reduction of hypertonia in patients with stroke.

Yeh C.Y.; Tsai K.H.; Su F.C.; Lo H.C. (2010).
Archives of Physical Medicine and Rehabilitation, 91(11): 1731-1736.

Abstract

Objectives: To evaluate whether a bout of leg cycling in patients with stroke reduces muscle tone and to determine whether neuromuscular functional electrical stimulation (FES) to the affected leg during cycling is more effective than cycling without FES.
Design: Within-subject comparison.
Setting: University hospital.
Participants: Patients with stroke (N=16; age range, 42-72y; <8wk poststroke) with hypertonia in the affected leg.
Interventions: Subjects' affected leg (1) performed cycling exercise with the assistance of FES (assisted-cycling session) and (2) performed cycling exercise without the assistance of FES (nonassisted-cycling session). Subjects sat in a specially designed wheelchair positioned on a resistance-free roller for each 20-minute session.
Main Outcome Measures: Changes in muscle tone pre- and posttest session were compared by using the Modified Ashworth Scale and the pendulum test (relaxation index and peak velocity).
Results: Modified Ashworth Scale scores were significantly lower (P<.05) and relaxation index and peak velocity values were significantly higher (P<.05) after both sessions. Changes in Modified Ashworth Scale scores, relaxation index, and peak velocity values showed a significant (P<.05) difference between the 2 sessions, and assisted cycling reduced hypertonia more than nonassisted cycling.
Conclusions: The hypertonia of patients with stroke showed a significant decrease immediately after a bout of leg-cycling exercise. FES-assisted leg cycling was better than nonassisted cycling for reducing hypertonia.

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