Cycling induced by Functional Electrical Stimulation in Stroke Patients: a systematic review and a meta-analysis of the evidence

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***Abstract*—Cycling induced by Functional Electrical Stimulation (FES) is a promising rehabilitative approach for stroke patients, mainly in the post-acute phase. This systematic review summarizes the current evidence about its effectiveness. Seven randomized controlled trials involving 221 subjects were found. Overall, a slight trend but no significant differences were achieved in favor of FES-cycling in walking speed and muscle strength. Further high-quality studies are advocated to derive an evidence-based conclusion about the effectiveness of FES-cycling in post-acute stroke patients.**

I. Introduction

STROKE is one of the major neurological disorders worldwide, with a high disability-adjusted life year rate [1], owing mainly to motor and sensory impairments. Experienced muscle weakness in the paretic lower extremity and reduced ambulation capacity commonly affect activity of daily living in stroke survivors [2].

Cycling induced by Functional Electrical Stimulation (FES) is a promising rehabilitative approach which employed synchronized electrical stimulation of multiple lower limb muscles during cycle-ergometer exercise [3]. The combination of FES and leg pedaling is a safe training which can be performed even in the post-acute phase and thanks to its similarity to locomotion, might have the potential to improve the recovery of walking ability. This review article summarizes the available evidence about the effects of FES-cycling on motor recovery in post-acute stroke patients.

II. Materials and methods

A. Criteria for considering studies for this review

We included truly randomized and quasi-randomized controlled trials. The primary question was whether FES-cycling (active or passive) could improve walking ability and muscle strength compared to cycling alone or usual care. Thus, we included trials that implemented FES-cycling alone or in addition to usual care in the experimental group and compared its effect to cycling without FES and/or usual care. The included studies had to recruit adults of any gender, with a diagnosis of a first stroke <6 months before study enrollment. The treatment effect was evaluated in terms of gait speed and strength of lower limb muscles [4].

Studies were excluded, in case only the abstract was available, or the numerical scores were not reported.

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B. Search methods for identification of studies

Up to January 2018, a comprehensive electronic search was performed in PubMed, EMBASE, CENTRAL, Scopus, Web of Science, PsychInfo, IEEExplore, Science Direct, OpenGrey and Google Scholar (first 1000 indexes) database engines. Ongoing trials were appraised in ClinicalTrial.gov and World Health Organization International Clinical Trials Registry Platform. The search strategy was adjusted for each database through appropriate Boolean combination of the following keywords: *functional electrical stimulation, electrical stimulation, neuromuscular electrical stimulation*, FES, *NMES, FNS, cycling, pedaling, ergometry, cycle ergometer, cycle training*.

All reference lists of retrieved studies were screened for additional eligible studies. No language, date and document format restrictions were applied to reduce publication and retrieval bias.

C. Data collection and analysis

Search results from different databases were merged and duplicates were removed. Titles and abstracts of identified papers were then evaluated, and irrelevant ones erased. For the remaining articles, full-texts were examined to evaluate studies eligibility.

Using Cochrane Collaboration's methodology [5], one of the review author (MP) assessed the risk of bias of the included study. The following criteria were evaluated: *random sequence generation, allocation concealment and blinding of outcome assessment*. Each of them was classified as 'low risk', 'high risk' or 'unclear risk' of bias.

Mean values, standard deviations and sample sizes were retrieved for the two selected outcome measures of the included trials. If a study provided medians, first and third quartiles, then means and standard deviations were imputed. In case of multiple experimental or control groups, they were combined to create a single pairwise comparison.

Once data of each study were extracted, a pooled estimate of the Mean Difference (MD) with 95% Confidence Interval (CI) was computed for continuous data using the same outcome measure. If studies reported continuous data using different outcome measures, the Standardized Mean Difference (SMD) with 95% CI was calculated. Fixed-effect meta-analyses were performed, if the level of heterogeneity was acceptable (I^2 statistic <50%); otherwise a random-effect model was used.

Review Manager version 5.3 was used for assessing risk of bias and performing the meta-analysis.

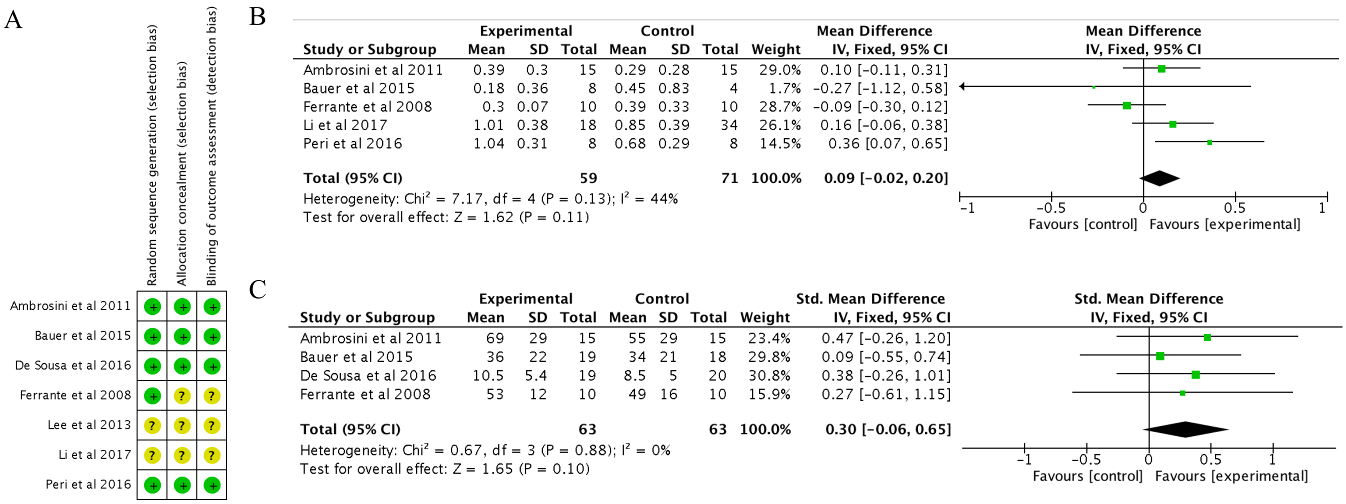

Fig. 1. Panel A: Risk of bias summary. Panels B and C: Forest plots of the main comparison at the end of treatment: FES-cycling in addition to Usual Care (Experimental) versus Usual Care (Control); Outcome 1, Gait speed in m/s (B) and Outcome 2, Strength of lower-limb muscles (C).

III. Results

From the 2416 retrieved records after duplicates removal, seven randomized controlled trials [3], [6]-[11] involving a total of 221 participants were included in the quantitative analysis of this review. In the majority of the studies (5), the experimental group performed active pedaling plus FES delivered to both sides [7] or only to the paretic side [6], [8], [10-11]; in the two remaining studies the experimental intervention consisted of passive FES-cycling (with both sides stimulated) [3], [9]. In all studies but one [11], FES-cycling was performed in addition to usual care. The effects were compared to cycling in addition to usual care [3], [8-9], cycling alone [11] or usual care alone [7], [10]. One study [6] had a three-arm design, with two comparison groups, one performing only cycling and one performing only usual care. Results of both control arms were pooled and compared with outcome measures of the experimental group.

The overall risk of bias was low for 4 studies, while for the remaining 3 it was judged as unclear (Fig. 1-A).

Five studies assessed gait speed at the end of the treatment, using the 50-meter [3], [9] or the 10-meter [6]-[8] walking test. The pooled MD [95% CI) was 0.09 m/s [-0.02; 0.65], revealing just a positive trend, but not a significant difference in favor of the experimental group (Fig. 1-B).

Four studies assessed lower limb muscles strength using the Motricity Index [3], [8], [9] or the Impaired Key Muscle Strength [10]. Overall, the results showed that FES-cycling did not improve significantly strength of lower limb muscles (SMD [95% CI of 0.30 [-0.06; 0.65].

IV. Conclusions

Overall, people receiving FES-cycling in addition to usual care in the early phase after stroke are not more likely to improve walking ability and muscle strength compared to patients receiving cycling and/or usual care alone. However, the current evidence is still very limited. More high-quality studies, with an adequate statistical, are required to investigate the effectiveness of FES-cycling after stroke.

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