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# FES Cycling in Persons with Paralyzed Legs: Force Feedback for Setup and Control

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## **Abstract:**

*Cycling assisted by functional electrical stimulation (FES cycling) has many positive effects on the overall health in persons with paralyzed legs due to the injury of the central nervous system (i.e., increases bulk of stimulated muscles, preserved range of movements in the joints, preserved cross-section geometry of long bones that are axially loaded, reduced body fat content, preserved functioning of the cardiovascular and pulmonary systems, reduced frequency of urinary infections, reduced spasticity in stimulated muscles). If the FES cycling exercise starts shortly after the central nervous system lesion, then the muscles will not be atrophied. The FES needs to provide sufficient muscle power to turn the pedals of the bicycle. If the pedals don't rotate, then the exercise would be discouraging for the patient and many among them would give up on this type of training. The FES assistance must provide strong enough stimulation that is tolerable by the user, and the correct timing of stimulation bursts to push and pull when needed. If the stimulation power is not sufficient, then the external power coming from the motor built into the exercise bike is required. The temporal pattern (on-off) need to match the pushing and pulling on the pedals at the appropriate positions to generate the driving momentum; hence, it is linked to the angle of the pedals (from 0° to 360°). The optimal setup of the temporal pattern benefits from the assessment of the interface force between the pedal and the foot. The driving torques will be optimal if the interface force is perpendicular to the lever.*

*We are developing a protocol for designing the optimal stimulation-motor assistance profile for the cycling based on the measurements of the interface forces. The setup uses the optimization criterion that maximizes the effect based on the asynchronous activation of synergistic muscles. The protocol is being developed for the therapy performed with Omega bike (Tyromotion GmbH, Graz, Austria) and Motimove FES stimulator (3F-Fit Fabricando Faber Ltd, Belgrade, Serbia). The same principle used for the setup can be used for closed-loop control to correct the original non-optimal temporal pattern.*

**Keywords:** FES, cycling, force feedback

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