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Computational methods to support clinical assessment in examination of walking ability - The regularity of muscle activities and smoothness of limb movement can be useful characteristics of walking patterns when rehabilitation training protocols are considered. Arm and leg cycling training may improve the walking abilitiy of individuals with incomplete spinal cord injuries (iSCI). Our objective was to identify additional metrics that could characterize these changes and provide quantitative support for clinical assessments of walking ability. We presented new computational approaches for this purpose. We demonstrate that hybrid functional electrical stimulation (FES) cycling can induce changes in the regularity of muscle activity signals and in the smoothness of leg movements during walking. We investigated the entropy of muscle activity and the smoothness of foot trajectory as a function of joint angular velocities, accelerations and jerks in an iSCI patient who participated in low-intensity hybrid FES cycling training. The entropy of EMG signals, recorded from knee flexors and extensors, decreased after training. Decomposing the jerk of the foot (the endpoint of the leg) into components related to joint angular velocities, accelerations and jerks, shows that the most dominant component is the one which is related to joint angular jerks. This is consistent with earlier results for reaching arm movements. For our participant, however, the contribution of this component to the total jerk was a bit different between the left and right legs (93% and 85% respectively). After the training, this contribution decreased with 21% on left side and 6% on right side, indicating a more balanced pattern in both legs. We conclude that the two methods, muscle activity entropy and jerk decomposition, provide valuable insight into changes in walking patterns and abilities. [1]

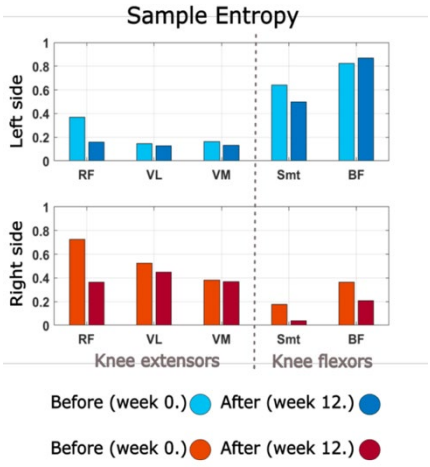
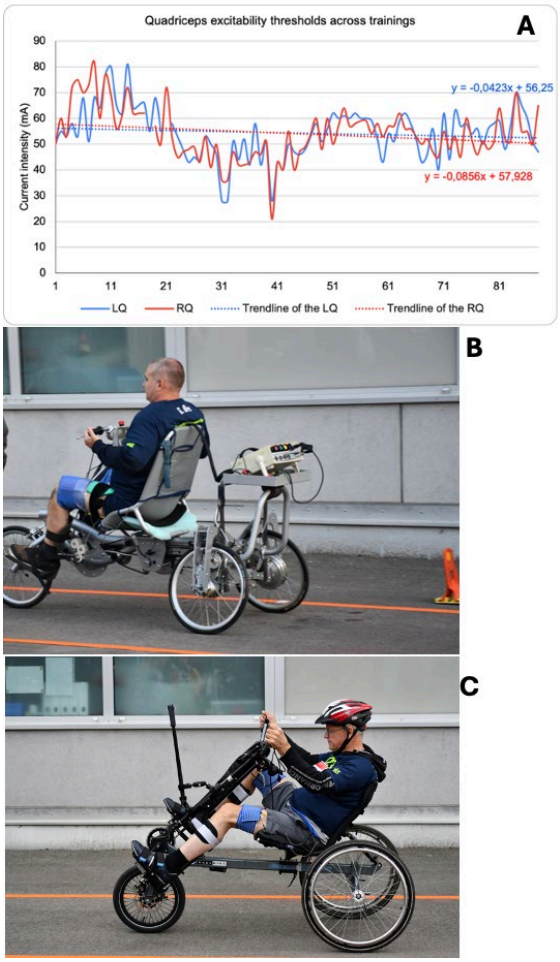


Figure 1: The sample entropy of the average electromyogram envelopes of the knee flexor and extensor muscles before and after the 12 weeks long hybrid FES cycling training. Left side (blue) and right side (red).

FES-induced changes in excitability of denervated muscles in flaccid paraplegia – single case study – We investigated the long-term changes in muscle excitability induced by functional electrical stimulation (FES) in a patient with flaccid paraplegia, in which the muscles had completely lost their innervation. A significant challenge in rehabilitation is how to preserve the muscle quality, contractility and mass. The aim of the study was to assess whether prolonged, early-started long-pulse FES training could improve muscle excitability and enable participation in FES-assisted cycling. Our participant sustained an injury three years ago resulting in complete sensory and motor loss below the Th8 level (ASIA A), due to an ischaemic spinal cord injury. Over a three-year period, he participated in regular muscle strengthening sessions using a Stimulette den2x stimulator, as well as FES-assisted cycling training using a specially modified Reha Funtrike tricycle, which was designed to directly stimulate denervated muscles. This tricycle is unique worldwide. Muscle excitability was quantified by motor threshold, defined as the minimum current intensity required to elicit



a visible muscle twitch. These thresholds were repeatedly measured over time: 86 times for the quadriceps, 40 times for the gastrocnemius, and 30 times for the tibialis anterior. The results showed a clear downward trend in motor thresholds, indicating improved muscle excitability. The mean quadriceps threshold decreased from approximately 63–64 mA in the first 20 sessions to 52–55 mA in the final 20 sessions. During resumed FES-assisted tricycle training, the cycling distance increased from 0.47 km to 1.1 km per training session, and the average cycling speed was higher in the final phase of the training sessions than in the initial phase. Heart rate increased during training and remained elevated post-exercise, reflecting the involvement of both the arms and legs. In conclusion, our study demonstrates that long-term, long-pulse electrical stimulation, when combined with FES, can enhance the excitability of denervated muscles and support functional FES cycling in cases of flaccid paraplegia.

Figure 2. A) The quadriceps muscles excitability thresholds during the sequence of 86 training sessions (LQ-left quadriceps, RQ-right quadriceps. B) Special tricycle equipped with an electrical stimulator for SCI patients with denervated muscles. C) BerkelBike tricycle

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