Influence of FES cycling on spasticity in subjects with incomplete spastic paraplegia

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Abstract. Commonly used methods for quantification of spasticity have shown controversial reliability. In this study we propose a method for quick determination of spasticity in spinal cord injured subjects on a cycling and measurement system. Measurements with test persons with incomplete spastic paraplegia have shown that spasticity is decreased after a 30 min cycling training with functional electrical stimulation (FES).

Keywords. spasticity, paraplegia, SCI, functional electrical stimulation

Introduction

Spasticity is a common problem among paraplegic subjects that can cause pain, lead to unwanted movements or prevent intended movements. Lance [1] defined spasticity as a motor disorder that is characterized by a velocity dependent increase in the tonic stretch reflex with exaggerated tendon reflexes. For quantification of spasticity manual scales, biomechanical techniques, or neurophysiological methods have been applied. Manual scales as the Ashworth Scale/Modified Ashworth Scale (MAS) are most commonly used but have shown a controversial reliability [2]. Krause et al [3] found that FES cycling training reduced spasticity (determined by MAS and pendulum test) in spinal cord injured (SCI) subjects.
The aim of this study was the assessment of spasticity in the lower extremities using the pedaling mechanism of a cycling system for paraplegics [4] and to quantify the influence of cycling training with FES on spasticity in SCI subjects.

1. Methods

1.1. The cycling and measurement system

The cycling and measurement system is based on a tricycle that was especially adapted for the FES training of paraplegic subjects (Fig.1). A motor that is mounted underneath the crank beam can move the cranks at a given angular velocity or hold the cranks at a defined position. Orthoses support the legs and fix the ankle joints. A 10 channel current controlled stimulator stimulates three muscles/muscle groups of each leg (m. quadriceps femoris, mm. hamstrings, and m. gluteus maximus) via attached surface electrodes. The motor current and the forces (Fr, Ft) applied to the cranks are continuously monitored during the therapy sessions.

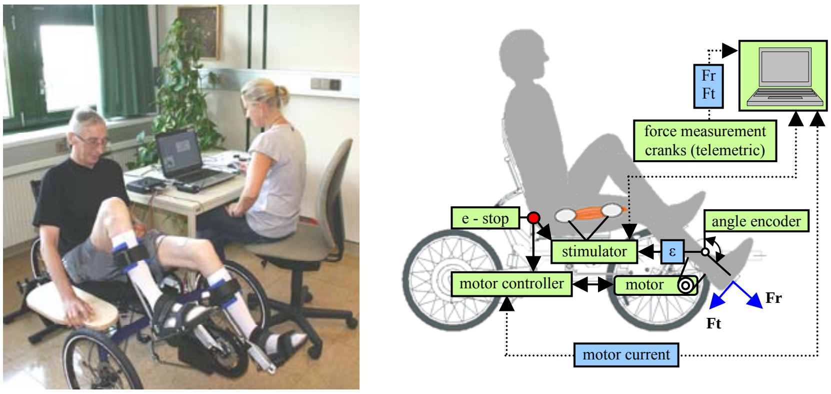

Figure 1: The cycling and measurement system during measurements and schematic of control

1.2. Measurements

Nine subjects with incomplete spastic paraplegia (2 femal, 7 male, age 38/ SD 16, time since injury 6.1 month/ SD 3.2, motoric lesion at L1-C6, ASIA B,C) volunteered for the study and gave informed consent. The training sessions in a period of 2 month were started with a short passive warm-up followed by the assessment of the patients' spasticity status. After a 30 min pedaling training with FES the spasticity test routine was repeated.
For the spasticity test routine the cranks were moved by the motor with constant angular velocity at 10/20/30/40/50/60 rpm, for 15 full rotations at each cadence. Therefore the patient was asked to relax to minimize his force inputs by active muscle recruitment. The subjects` geometrical position was adjusted to allow a maximum knee angle of 160°. The maximum angular velocities of knee and hip joints were about 230°/s and 160°/s, respectively.
The applied motor current is corresponding to the resistance of the legs against the movement. For evaluation the current values were averaged over 10 full rotations at each cadence.

2. Results

The results of 7 to 14 training sessions were averaged for each patient. Figure 2 shows a comparison of the results of a non-spastic test person (MAS 0) and a test person with an averaged MAS of 1.5 that dropped to 1.2 after the FES training. For non-spastic subjects resistance was usually slightly decreased after the FES training over the whole range of velocities, the curves run in parallel (Fig. 2, left side). Basically, the increase due to inertia is the same before and after the FES training. Consequently, if the difference between the two curves increases at higher velocities as in the right sided graph in Fig. 2, it can be assumed that this effect originates from the spasticity.

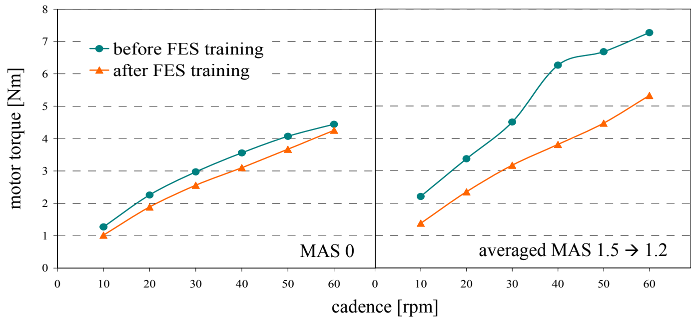

Figure 2: Comparison of averaged results of a non-spastic test person P1 (left) and test person P3 with MAS 1.5 on average before the FES training (right)

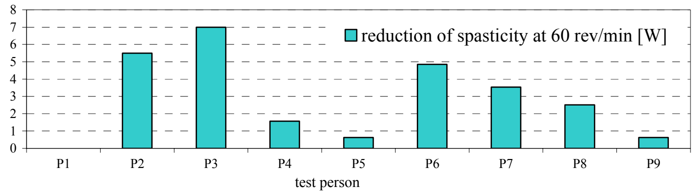

Figure 3: Reduction of spasticity in Watts at 60 rpm after the FES cycling training

Figure 3 shows the reduction of spasticity for all nine test persons, calculated as the diverence of necessary drive power before and after the FES cycling training. The general relaxation of the passive structures is taken into account by subtracting the difference in motor torque at 10 rpm. Test person P3 reaches the highest value of reduction, 7 W at 60 rpm, for the non-spastic test person P1 the value is 0.

3. Discussion and Conclusion

The proposed method of spasticity assessment has the advantage, that the spasticity of both hip and knee joints is included in one test routine. The results show that spasticity is decreased after the cycling training with FES. This is in line with the subjective feelings of the patients after the training. A permanent decline of spasticity can not be reported.

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