Postural Balance Improvement Using Dermatome Electrical Stimulation Therapy in Incomplete SCI Patients

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Abstract

The objective of the study was to quantify and evaluate the effectiveness of dermatome electrical stimulation on postural balancing. Artificially induced perturbations in eight different directions were provided to the person standing in the modified BalanceTrainer. Simultaneously electromyograms (EMG) of selected muscle groups (tibialis anterior, soleus, tensor fasciae latae and quadriceps) were recorded while an incomplete SCI subject (Th 3-5) was standing on two force platforms before and after 20 min. of L3-4 dermatome stimulation therapy. Decrease of quadriceps spasticity and improved postural responses were noticed.

1. INTRODUCTION

Our group has been involved in functional electrical stimulation (FES) for several decades. We have applied FES efficiently to several incomplete spinal cord injured (SCI) patients as well as paraplegic patients to restore walking or as a part of therapy for the gait restoration in the rehabilitation unit and also put an emphasis on studies of functional postural standing [1]. The main issue was the identification of central neural system (CNS) control strategies by observing the kinetics, kinematics and muscle activities during quiet and perturbed stance.

Later on we put more emphasis on FES for therapeutic purposes within the rehabilitation institute. Surface dermatome electrical stimulation, one of the possible accesses to the spinal neural circuitry from the periphery has been successfully applied in incomplete SCI during treadmill walking [3]. Most of the patients to whom FES has been applied in the rehabilitation unit recover and notice a significant improvement of their walking and standing ability. The walking performance may be evaluated by several parameters as speed, cadence, and step length even without further kinematic and kinetic analysis. But standing performance is rarely evaluated in the sense of comprehensive qualitative assessment. Such evaluation takes effect in daily life of every patient who took part in the rehabilitation program and may inspect his clinical progress.

In this study the aim is to investigate the impact of dermatome electrical stimulation therapy on postural responses during perturbed standing.

2. METHODS

A novel postural training device BalanceTrainer (Medica GmbH, Germany) has been modified in a way that artificial postural perturbation in eight different directions (forward - FW, forward-left – FL, left – LF, back-left – BL, backward – BW, back-right – BR, right – RT, forward-right – FR) can be applied to the person standing in the frame (Fig.1). An operator using a personal computer is given a choice of direction and power of perturbation that is provided to the person standing in the frame. Simultaneously the person standing in the frame is standing with each foot on separate force platforms (AMTI Inc.), measuring 3-DOF forces and moments. During standing in the frame also the muscle activity was recorded with surface electromyography EMG (Noraxon, Inc.).

2.1. Dermatome Electrical Stimulation

It has been shown that the hip and knee spasticity can be reduced through cutaneous stimulation of the selected dermatomes. When the electrodes are placed over the L-3,4 dermatomes the aim is to relax the knee and hip extensors, innervated from the same spinal cord level as the dermatome. In such manner the decrease of spasticity may be expected.

2.2. Protocol

A group of healthy subjects and incomplete SCI patients were candidates for postural balance assessment and evaluation. Not all incomplete SCI patients were able to stand in vertical

position without support or had major problems with balancing when the artificially invoked perturbation was applied. Therefore we focus on case study with incomplete SCI patient (chronic Th-3-5, 89kg, 178cm, 18 years after injury) who was not able to move his lower extremities, but showed almost no difficulties with postural balancing. Hereby the BalanceTrainer training device was used as postural balance assessment tool. The device imposed the perturbation to the patient on operator's command. The directions in the protocol were as follows: BL-FW-FR-LT-BW-BR-FL-RT. The assessment procedure was repeated four times to assure sufficient data.

Figure 1. Modified BalanceTrainer for postural perturbation

During the perturbation the EMG of the tibialis anterior (TA), soleus (SOL), tensor fasciae latae (TFL) and quadriceps (QUA) were assessed to supplement the ground reaction forced measured by two separate force plates under each foot.

After the assessment the electrodes were placed over the L-3,4 dermatomes, 1 medially below the knee and the other laterally above it, with the aim to relax the knee and hip extensors, innervated from the same spinal cord level as the dermatome. A stimulation of 100Hz and pulse duration of 0.3ms were provided for 20 min while the patient was in the sitting position. Immediately after the stimulation the postural balance assessment procedure was repeated.

3. RESULTS

As we expected the spasticity in quadriceps was noticeably decreased as it can be seen in the linear envelope EMG in the upper right figure in Fig.2. The ground reaction forces show a quicker and less lopsided response. Also the patient's response time has been shortened despite it is not that enormous, but only noticeable.

The centre of pressure (COP) analysis (Fig. 3) shows more controllable response to the perturbation on the left side (FL, LT, BL) after the dermatome stimulation.

The normalized EMG at selected moments (0, 300, 500, 800, 1100 and 1600 ms after the perturbation (Fig. 4) – the exact moment was detected by goniometer/tilt sensor) shows the activity of selected muscle groups. Most of the postural balancing was managed by TA and SOL and also some activity of the TFL can be noticed, all much more expressed after the dermatome stimulation. In lower row of the figure the decrease of the QUA activity after dermatome stimulation can be noticed.

4. DISCUSSION AND CONCLUSIONS

The FES is an indispensable approach in muscle re-strengthening and in-patient rehabilitation of incomplete SCI and paraplegic persons, sometimes in combination with

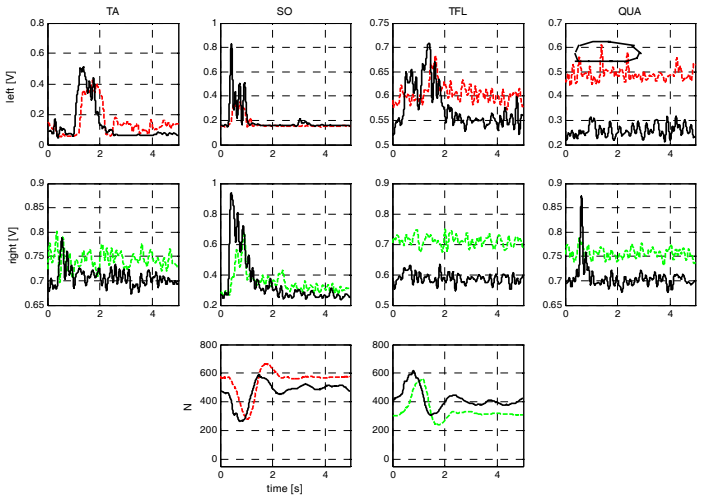

Figure 2. Time course of the EMG linear envelope of TA, SOL, TFL, QUA shows a decrease of QUA spasticity (spikes in upper right) after dermatome stimulation (solid line) and faster and less lopsided response.

treadmill and/or body weight support. In the last years we have been investigating the impact of the FES training on postural balancing when artificially induced perturbations randomly impede the normal posture in the balancing frame. We came to the conclusion that not only muscle strengthening plays the important role in postural balancing but also the CNS control recovery [1].

The time-course of EMG gave us a vast picture of patient's activity and also shows a progress in postural balancing. But unfortunately we may not speak of the significant improvement until the patient will not notify us about his satisfaction with the progress. If so, then we achieved the goal.

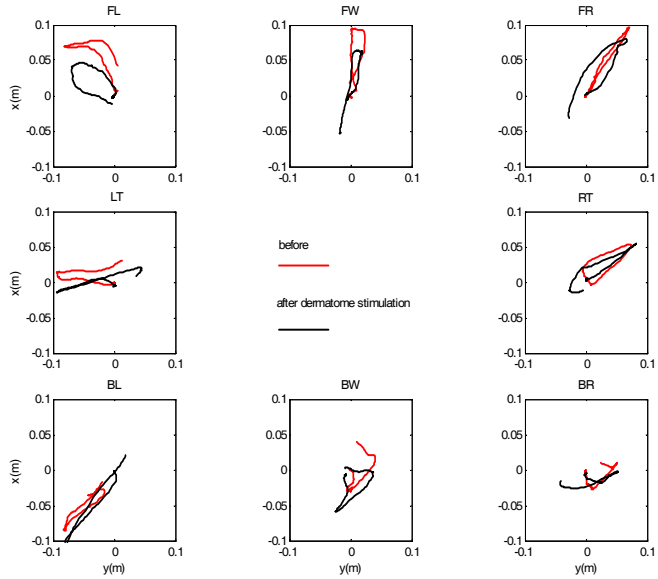

Figure 3. The analysis of the centre of pressure shows more controllable response to the perturbation on the left side (FL, LT, BL) after dermatome L3-4 stimulation of the incomplete SCI person (Th-3-5).

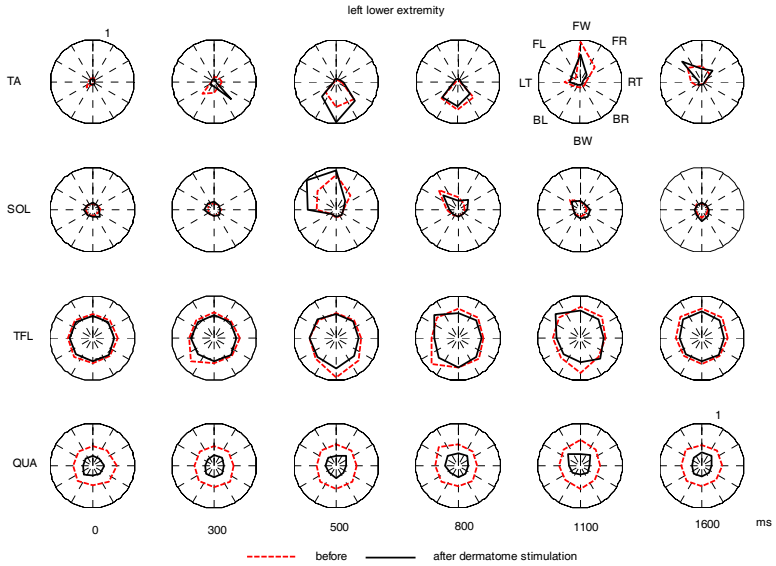

Figure 4. The normalized EMG at selected moments shows the activity of selected muscle groups before and after dermatome L3-4 stimulation of the incomplete SCI person (Th-3-5). Most of the postural balancing was managed by TA and SOL (more expressed after stimulation) and also some activity of the TFL can be noticed.

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