Evaluation of robotic gait training in stroke through EMG investigation

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Abstract—Stroke is a leading cause of acquired disability in adults worldwide. To face this problem, wearable robotic exoskeletons can provide high doses, immersive gait rehabilitation, allowing an early mobilization of lower limbs in patients who are unable to maintain the upright position or trunk control. For these reasons, exoskeleton assisted gait training is nowadays proposed in addition to standard therapy to improve stroke patients re-learning. The present work aims to evaluate the impact on muscular activity of gait training assisted by the commercial wearable exoskeleton Ekso GT™ (Ekso Bionics, USA) in sub-acute hemiparetic stroke patients. Timing and amplitude of muscular activation were investigated through the Electromyography system (BTS Bioengineering, Italy). Signals were acquired using the FREEEMG wireless electromyography system (BTS Bioengineering, Italy). Signals were immediately after the treatments (T1).

Methods

Participants were recruited from outpatient and inpatient services at the Villa Beretta Rehabilitation Centre (Costa Masnaga, LC, Italy), after the approval from the Ethics Committee of the clinical center. All subjects gave informed written consent in accordance with the Declaration of Helsinki. The overall intensity of the rehabilitation treatment was comparable between the two groups, i.e. 20 rehabilitation sessions, including standard physiotherapy and robot-assisted rehabilitation. Patients were evaluated at baseline before (T0), and immediately after the treatments (T1).

Muscular activity assessment

For both groups of patients, EMG signals were acquired bilaterally from four lower limbs’ muscles: tibialis anterior (TA), soleus (SOL), rectus femoris (RF), and semitendinosus (ST). Signals were acquired using the FREEEMG wireless electromyography system (BTS Bioengineering, Italy). Signals
were acquired during a single session of free walk overground at T0 and T1. EMG signals from the same four muscles and in the same experimental conditions were also acquired from seven healthy subjects during five consecutive walking trials to derive the normative pattern.

A standard pre-processing was applied to the acquired EMG signals, including high-pass filtering with a 3rd order Butterworth filter at 20 Hz, rectification, and low-pass filtering with a 3rd order Butterworth filter at 4 Hz. For each subject, EMG signals of single steps were averaged in time and amplitude. They were then normalized to their own maximum amplitude, and rescaled in time to the mean step duration [3].

D. Gait metric

The Gait Metric (GM) index [4] was extracted from the muscles’ activation profiles of the healthy population and the patients’ groups. This index was used to estimate the similarity between participants’ muscular activity and the normative physiological activation profiles. In particular, GM performs a combined evaluation of muscular activity amplitude and timing. The GM was extracted separately from the four recorded muscles and from groups of muscles. In particular, we merged the distal and proximal muscles (both from a single limb and both limbs), the 4 muscles belonging to the same limb, and all the 8 analyzed muscles together.

III. Results

A. Participants

The group of healthy subjects included four males and three females, with a median age of 30 years (23-32). Patients were divided into two groups of 14 subjects. The CG included 11 men and 3 women, and the median age was 68 years (66.25-70.75). They performed 20 sessions of traditional physiotherapy. The EG group, instead, involved 9 men and 5 women, with a median age of 65 years (53.25-73.75). The number of sessions with Ekso ranged from a minimum of 14 to a maximum of 14 per patient.

B. Gait Metric

No significant difference was found between CG and EG for the GM index (p-value>0.370) at baseline (T0), therefore the groups were considered homogeneous before the intervention.

The CG did not show significant differences between T0 and T1 for any of the muscles analyzed (p-value<0.05). In the EG, a significant improvement in GM was found for the muscles of the non-paretic limb (p-value=0.015) and the pair of non-paretic proximal muscles (p-value=0.025) (Fig. 1).

IV. Discussion

This work aimed to evaluate the impact of Ekso-assisted therapy on stroke sub-acute hemiparetic patients, with a comparison with traditional physiotherapy, focusing on the Gait Metric index. The analysis of GM between T0 and T1 for each group of patients showed that the traditional therapy alone did not lead to significant changes, while the addition of the exoskeleton assisted therapy brought significant improvements in terms of amplitude and timing of muscular activity. These improvements concerned the non-paretic proximal muscles. It can be assumed that the greatest effect of the therapy on the proximal muscles was due to the greater impact of Ekso on the terminal stance phase, crucial for the control of the knee joint [5]. The greater improvement of the proximal muscles compared to the distal ones could also be related to the mechanical characteristics of Ekso, which concentrate its active support at the hip and knee level. In addition, the weight support function performed by the exoskeleton decreased the plantar flexion of the subjects, reducing the SOL activation [6]. The different impact of Ekso on distal and proximal muscles had been already observed in some studies in the literature on chronic stroke patients rehabilitated with Ekso [5] and in the EMG signals acquired by sub-acute patients during Ekso-assisted walking [6].

These considerations support the hypothesis that Ekso training guides the re-learning process toward a healthy pattern. Future works should perform the same analysis of muscular activity indexes on a greater number of subjects using a randomized controlled trial with a long-term follow-up to evaluate the stability of the therapy-induced improvements through time.

REFERENCES