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 muscle 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 Gait Metric index. Results suggested that exoskeleton-assisted therapy has been more effective than the standard physiotherapy in promoting the recovery of the non-paretic side muscular activity. These considerations support the hypothesis that Ekso training guides the re-learning process toward a healthy pattern.**

***Index Terms*—Exoskeleton, Gait training, EMG, stroke**

I. Introduction

Stroke is one of the leading cause of acquired disability in adults worldwide [1]. Robot-assisted rehabilitation can offer new promising possibilities. Indeed, the use of a robotic device promotes neural plasticity by providing safe environmental conditions to perform repeated and immersive exercises that can be tailored to patients' residual abilities. Since 30-40% of stroke survivors have limited or no walking ability even after rehabilitation [2], gait recovery is still one of the main goals of post-stroke rehabilitation, and there is an ongoing search to advance the effectiveness of gait training for stroke survivors.

The efficacy of robotic overground assisted gait training in improving motor and functional outcomes in stroke patients is controversial and widely discussed in literature [2], and it has been assessed mainly using specific clinical scales and tests (e.g., Modified Ashworth Scale, Walking Handicap Scale, Motricity index). These clinical outcomes are particularly useful in the assessment of gait performances, but they only relies on behavioral evaluations performed by physiotherapists and do not include objective measures coming from sensors or systems of measures. When coming to muscular activation, similar kinematics and values of gait relevant parameters (e.g., endurance velocity, walking speed over short distances, independence in the activities of daily living) might come with different muscular activity. The study of muscular activation is the best peripheral and functional point of extraction of information about changes at the brain level, and may inform about effective social return.

This work investigates the gait rehabilitation process on 28 sub-acute stroke patients and evaluates the motor re-learning analyzing the EMG profile. In particular, the study compares the rehabilitation therapy assisted by the commercial wearable exoskeleton Ekso GT™ (Ekso Bionics, USA) to standard physiotherapy. Preliminary results of this study concerning classic clinical scales did not show significant difference between the two involved groups [2].

II. Methods

A. Participants

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. They were diagnosed with a first-ever stroke, the interval from the acute event ranged from 2 weeks up to 6 months (i.e., sub-acute patients), and affected by lower limb monoparesis with a level of spasticity at the hip, knee, and ankle <3, as detected by Modified Ashworth Scale.

B. Experimental set-up and protocol

This study involved the use of an overground wearable powered exoskeleton: Ekso GT™, Ekso Bionics, USA. Enrolled patients were divided into two groups: i) Control Group (CG), that performed traditional rehabilitation therapy, and ii) Experimental Group (EG), that underwent also Ekso-assisted gait rehabilitation in addition to conventional therapy. 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).

C. 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 18 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).

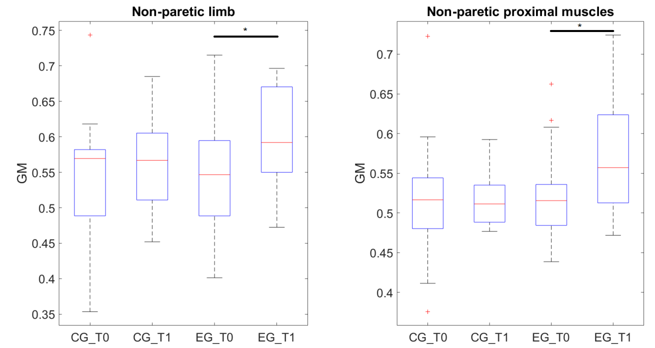

Fig. 1. Gait Metric (GM) comparison between Control Group (CG) and Experimental Group (EG) concerning patients at pre (T0) and post treatment (T1) time.

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.

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