HANK exoskeleton: usability study and first impressions from a physiotherapeutical point of view

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Abstract— **HANK is an exoskeleton for the lower limbs intended for the rehabilitation of gait after spinal cord injury, strokes and neurodegenerative diseases. A SCI patient overcame 12 therapy sessions lasting one hour and a half, involving walking with a body weight support system and on the parallel bars, both wearing the exoskeleton, at a comfortable selected speed. We gathered the comments of the physiotherapist on the usability of the device for the real scenario of the daily clinical practice.**

I. INTRODUCTION

HANK [1] was developed by the Neural Rehabilitation Group of the Spanish National Research Council (CSIC) [2] and Gogoa Mobility Robots S.L. [3]. During rehabilitation with exoskeletons, neuroplastic mechanisms are potentially activated [4], [5], [6]: neurons are able to stably increase their connections with other neurons, generating new neuronal sets, as a result of experience, learning and sensory and cognitive stimulation.

In this contribution, we have gathered the comments of the physiotherapist while and after performing the therapy with HANK.

II. METHODOLOGY

A. Patient

We enrolled a male subject, 41, 1.80 metres tall and 80 kilograms. The level of the lesion of the spinal cord injury (SCI) patient was T4.

The patient lacks any ability to walk before the start of sessions with HANK.

This usability study was carried out at Onbideratu neurorehabilitation center (Urretxu, Basque Country, Spain). It was carried under usability engineering techniques according to EN 62366-1: 2015 with the aim of evaluating the ease of use and safety of the device at the Onbideratu center.

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B. HANK exoskeleton

HANK is a standard solution that aims to adapt to the majority of the population, therefore, it is a system adjustable in height and articulations by means of quick-mooring fixings.

HANK consists of brushless motors at each of the six joints (left and right hips, knees and ankles) in the sagittal plane, and sensors for measuring the interaction force. It is possible to adjust the assistance level independently per joint, as well as controlling each joint's range of motion.

The exoskeleton provides the possibility to walk "step by step" (to perform isolated steps) or in "walk" mode (continuous gait, to potentially activate the central pattern generators on the fly). In "walk" mode, the speed is adjustable and can be raised and lowered on the fly.

HANK is 650 millimetres wide, weights around 15 kilograms, and can be adjusted to users from 1.50 to 1.90 metres high.

C. Experimental protocol

The therapy consisted of one hour and a half long sessions, three per week, for 12 weeks.

The sessions consisted of continuous gait along a 10 metres track with the exoskeleton at the speed comfortable for the patient each day, supported by a partial body weight support crane. After eight to ten repetitions, depending on the day, the patient was moved to a three metres long track with parallel bars. The patient had to support his own weight while the exoskeleton was moving his legs. This exercise was performed four times.

III. RESULTS

We detail in this section all the observations done during the rehabilitation process assessed in this usability case study, from the clinical (related to the patient and rehabilitative process) and technical (about the device) points of view.

Clinically, the device was able to: 1) Increase in the range of motion of the lower limb joints, that was lower to the normality prior to the beginning of the therapy: we observed an increase of the range of motion towards dorsal flexion of the right ankle (the patient had a history of malleolus (tibial and peroneal) fracture); 2) improve muscle tone; 3) increase of the muscular strength in the antigravity musculature and in that necessary for the gait: abdominal, oblique, paravertebral, lumbar squares, glutes, quadriceps, hamstrings, triceps surae; 4) increase straightening actions and self-elongation capacity; 5) show a sensitivity increase at the injured body areas; 6) increase static and dynamic balance; 7) promote the acquisition of the ability to take steps (not walking) autonomously; 8) decrease the intensity and frequency of neuropathic pain; and 9) promote respiratory changes towards a diaphragmatic pattern.

From a technical point of view, some drawbacks were observed: 1) the exoskeletons lacks the capacity to start in "walk" mode with the left foot; 2) after stopping and starting again in "walk" mode, HANK walks at the same speed as it had before stopping; 3) the connection bars between joints tend to bend laterally, mainly at the first stages of the treatment, when the device needs to provide more support as the patient usually has lower stability; and 4) the foot plates do not fit all the footwear, mainly wider.

IV. Conclusion

Clinically, multiple benefits (structural, functional and occupational) have been observed thanks to the use of HANK.

Due to the increase in the injured areas sensitivity, there was an improvement of the body scheme and perception. This improvement, together with the positive results shown, improved motor control of the lower extremities, reducing, for example, hyperextension of the knee in the load phase.

The changes presented in results also lead to greater stability (in trunk and pelvis) both in sitting and in static standing, improving the posture of patients. We also observed improvement in reach movements, thanks to greater stability in the trunk and pelvis.

One important outcome of the therapy with HANK was the improvement of the respiratory cycles.

From a technical point of view, the exoskeleton with its six sagital-plane-motorized joints, allows providing normotypic gait trajectories, as well as assisting both complete lower limbs.

Furthermore, the control system allows to: 1) adjust the range of motion per joint, either limiting them when there are physiological restrictions, and emphasizing them when needed to avoid compensation; and 2) adjust assistance per joint, useful in cases of hemiparesis.

The device, permitting the change of gait speed, leads to potentially activating the central pattern generators for gait.

This control system provides the capacity to adapt the product to the specific needs of each patient, making rehabilitation with HANK very patient-focused; thus providing the therapist with a lot of control in planning and progressing in therapy.

The device can be used with walking aids (walker, crutches ...), due to its dimensions. Furthermore, due to its weight, it can be handled by therapists during rehabilitation. The device required no previous training for the therapists to donning and doffing the device, and lead to times of ten minutes for donning and three for doffing.

The patient, injured at T4 level, was given good stability, and was also provided good support at the knee level, preventing its flexion.

Regarding the technical problems, the most important from the neuro-physiological point of view is that the exoskeleton only starts gait with a right step, leading to the central pattern generators involved in gait to learn that they can only start walking by taking a right step. This should be reviewed, as it is providing the central nervous system with the information of being able to start gait just with the right foot, while in daily life there may be setbacks that force the individual to start walking with the left foot.

The speed the device starts at after stopping gait is the speed it had when stopping, and it cannot be lowered while stopped, making it difficult for patients to restart gait. It should be possible to lower it before restarting gait.

Although the adjustability in height provides a wide variety of user heights, it should noted that a large volume of potential patients are shorter than 1.50 metres high, thus making this device therapy unreachable for them. Furthermore, the bars connecting joints, when used with taller and/or heavier patients, tend to bend laterally, presenting a problem, mainly in patients with hypotonia, potentially leading to instabilities.

Finally, the foot plates are too narrow for some footwear, that is usually wider in some patients with vascular problems (one of the typical hassles with stroke survivors and SCI patients).

These aforementioned difficulties have not interfered with the progress of the treated patients, although it is considered that they had to taken into account for future changes in the exoskeleton and consequent improvements in the product and service offered.

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