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Training for a running competition with a wearable robot - a patient's journey

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Abstract: Aerobic exercise performed with moderate to vigorous intensity and the use of wearable robots may be effective in addressing physical deconditioning and negative cardiometabolic health consequences in individuals with Spinal Cord Injury (SCI). In this paper we demonstrate a case study in which a participant with SCI engaged in a ten-month, non-clinical training program using a wearable robot. Following the training, an 8% increase in the 2-minute walk test distance and increased training motivation was observed. These findings suggest that community-based mobility training with wearable robots may be a feasible and effective training option for individuals with lower-limb impairments.

I. Introduction

Approximately 40 million individuals experience Spinal Cord Injury (SCI) annually [1]. As the illness progresses from the acute phase to the chronic phase, the frequency of clinically-supported therapy usually decreases [1]. This, coupled with a commonly sedentary lifestyle, can lead to a physically deconditioned state in SCI-affected individuals compared to the general able-bodied population [2]. To address some of the negative cardiometabolic health consequences of SCI, adults with SCI are advised to engage in moderate to vigorous intensity aerobic exercise for at least 30 minutes, 3 times per week [3]. However, SCI-affected individuals may face physical, psychological, and environmental barriers to physical activity, making this recommendation challenging to follow [3]. Therefore, promoting physical activity in people with SCI may require addressing factors such as environmental accessibility, establishing meaningful goals, continuously monitoring progress, and exploring personal motivation [4], [5].

Considering the barriers to physical activity faced by SCI-affected individuals, wearable robots have the potential to support mobility-focused training in community settings for those capable of at least limited household ambulation. Specifically, wearable robotics may enable subjects to train outdoors, provide onboard sensor data for continuous progress monitoring, and potentially improve training motivation [6]. However, there are currently only a limited number of studies investigating the use of wearable robots in non-clinical settings, particularly in combination with a defined long-term physical activity goal.

This paper presents the analysis of a case study of a ten-month training program with a wearable robot performed by an individual with chronic SCI towards a defined mobility goal. The objective of this paper was the evaluation of wearable robots for rehabilitation in a non-clinical setting and determining the benefits of these devices for individuals with impaired lower limb function. As part of a larger investigation of the feasibility of wearable robotics in non-clinical rehabilitation and training settings, the results of this study will contribute to future research on the use of wearable robotics for unassisted home and community rehabilitation for individuals with reduced walking capacity.

II. Materials and methods

II.I. Participant

A single impaired male (34 yrs, 180cm, 110kg) with chronic SCI (sub-L2, AIS D) participated in this case study.

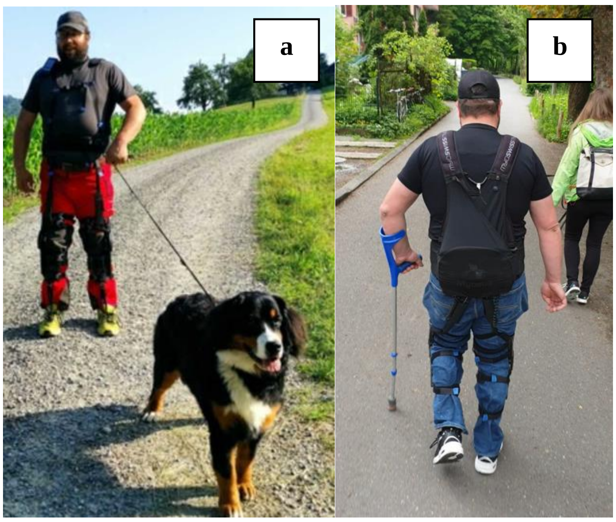

Figure 1: Participant with a chronic SCI diagnosis using the Myosuit for training outside of a clinical environment. In (a), the participant is using it for an activity of daily living, e.g., walking his dog. In (b), the participant is taking part in the Wings for Life run in Zurich, Switzerland.

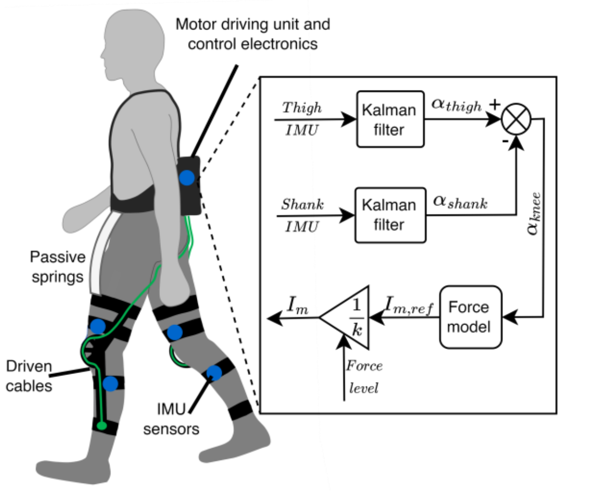

Figure 2: Schematic representation of the Myosuit and its active support control algorithm. The IMU data is used to calculate the knee joint angle α_{knee}. The joint angle is then used to calculate the reference force and corresponding motor current $I_{m,ref}$. This current is scaled based on the user's chosen level of assistance before being fed to the motor controller.

II.II. Wearable robot

The Myosuit (MyoSwiss AG, Zurich, Switzerland), a lightweight wearable robot, was used in this experiment. It is a medical device that partially supports the lower limbs during activities of daily living (ADL) for those capable of at least limited household ambulation. It uses compliant polyethylene cables to actively transmit forces from a motor-driving unit to each leg, providing extension torque at the hip and knee joints during the stance phase. The Myosuit also includes passive adjustable springs that provide hip flexion assistance during the swing phase of the gait cycle. The user's body model is estimated at 100Hz frequency using five IMUs mounted on the shank, thigh, and trunk segments of the robot's user. The Myosuit provides active support (visualized in Fig.2) during the stance phase, initiated upon the detection of a heel strike using a modified algorithm from [7]. The level of assistance is modulated based on lower limb kinematics and knee joint angle and can be adjusted to each user over 6 support levels.

II.III. Study setup and data acquisition

The participant approached the authors with the goal of participating in the *Wings for Life* charity run in Zurich, Switzerland, and covering a distance of at least 6km before being eliminated. At the start of the training, the participant's maximum distance estimation was 2km. Ten months in advance, the participant was provided with the Myosuit for use during training sessions and instructed to use the device during activities of daily living where it may be beneficial. The participant was responsible for donning and setting up the robot's assistance level for each training session without external help. The participant's raw IMU data was processed to extract various gait cycle events and spatiotemporal parameters for subsequent use in training progress monitoring. The maximum distance walked in the 2-minute walk test (2MWT) was recorded at the beginning and end of the experiment to assess any improvement. The total number of steps taken during each training session was also calculated as the primary measure of average weekly and cumulative performance.

III. Results and discussion

In total, the participant completed an average of 4 training sessions per week, for a total of 172 sessions with an average duration of 117 minutes and with an average support level setting of 2/5. The participant took a total of 1,052,563 steps and used the Myosuit for ADLs such as walking with a dog and standing at work. The performance results show high training motivation due to the clearly-defined training objectives and the use of assistive technology. The participant also reported improved perceived walking stability during the training, attributing it to the use of the wearable robot. After the training period, clinical personnel noted a clinically significant 8% increase in the 2MWT distance. This indicates that the training had a noticeable and positive clinical impact. The participant achieved a distance of 3.8 km before being eliminated from the competition and reported being satisfied with the result.

The results of this study suggest that community-based mobility training with wearable robots featuring personalized assistance is feasible for individuals with lower-limb impairments and may increase motivation.

IV. Conclusions

The results of our study suggest that wearable robots may have potential as a feasible solution for community-based rehabilitation and may support physical activity training in non-clinical settings. To increase the adoption of this technology, further research focused on personalizing the wearable robot's assistance and integrating them into goal definition, monitoring, and reporting may be beneficial.

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Author's statement

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