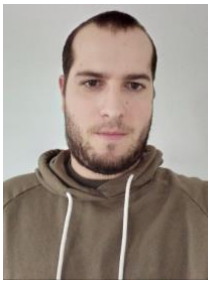
Development and Performance Evaluation of a Position-adjustable Rehabilitation System: Functional Movement Stimulator



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Introduction

The Functional Movement Stimulator (FMS), a multipurpose rehabilitation device, seeks to leverage limbs-cooperative training exercises, such as arm-leg cycling, rowing, and standing-up, to improve voluntary control over impaired limbs [1]. This thesis aimed to improve the mechanical and control systems of the FMS. Specifically, the functions of rowing and changing between the sitting and standing positions had to be investigated, and arm-leg cycling had to be improved. The overall functionality also had to be evaluated with an SCI participant.

Materials and Methods

The mechanical structure was designed in NX Siemens, and the software used to program the motion control is TwinCAT3.

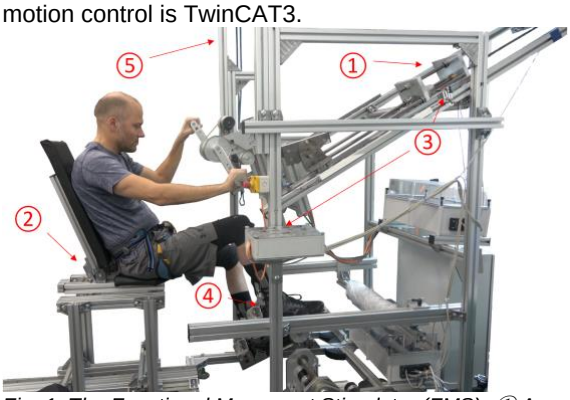

Fig. 1. The Functional Movement Stimulator (FMS). ① Arm drive sliding system, ② seat system, ③ safety components, ④ orthoses, and ⑤ body support frame.

The main part of the thesis was developing a motion control program that coordinates the seven motors. Over time, the cooperation between motors is susceptible to desynchronization. An algorithm had to be implemented to prevent this phenomenon from occurring during arm-leg cycling. The algorithm regulates the motors' speeds according to their relative positions. Rowing was achieved by operating the arms' motors in torque mode and the legs' and feet' motors in speed mode, matching the speeds of the arms. In the stand-up exercise, the motor block of the hands' motors rises to provide a grip for the subject. Preliminary tests were performed on the FMS with healthy subjects and a patient with a c6-7 spinal cord injury, ASIA B incomplete.

Results

The self-synchronization algorithm implemented for arm-leg cycling effectively reduced the lags for all axes at every speed analyzed. The mean normal force measured during a pedaling cycle within the speed interval of 3-10 rpm did not show a speed-dependent trend. However, different speeds yield different force distributions along the pedaling cycle.

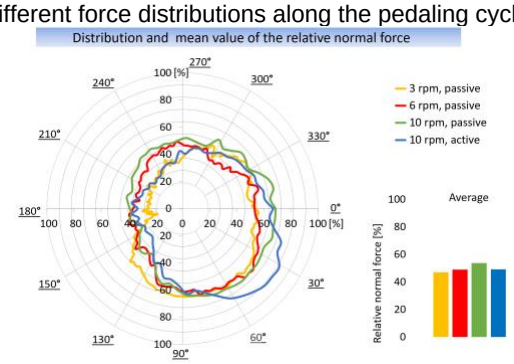

Fig. 2. (Left) Distribution of the relative normal forces in function of the angle. (Right) Average value of the relative normal forces.

For rowing, the measurements show that the speeds of the legs' motors follow the speeds of the hands' motors, while the speed of the feet' motors plateau at 12 rpm.

Discussion

With this thesis, the Functional Movement Stimulator was developed to the point of being able to perform tests. It is now possible to perform cycling, rowing, and standing-up movements. One can vary the intensity and speed of the exercises and quickly change from one activity to the next. Further software improvements are necessary to mitigate the phenomenon of axes misalignments during the rowing exercise and ensure the patient's complete safety.

References

[1] Fang J, Xie Q, Yang GY, Xie L. Development and Feasibility Assessment of a Rotational Orthosis for Walking with Arm Swing. Front Neurosci. 2017 Feb.

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