FES rehabilitation platform with real-time control and performance feedback.

Conference or Workshop Item

School of Biological Sciences

University of Reading

FES rehabilitation platform with real-time control and performance feedback

I.D. Zoulias | M. Armengol | R. Gibbons | A. Poulton | B. Andrews | W. Holderbaum

Introduction

Osteoporosis after spinal cord injury is associated with low-trauma fractures, and consequently with increased risk of morbidity and mortality. The loss of bone mass density (BMD) due to paraplegia can be reduced through cyclical electrically-induced muscle contractions [1]. Here we propose an FES control system based on posture switching [2], that induces transient loading of the lower limbs during a set of standing postures. This aims to produce an increased, evenly distributed BMD, whilst minimising FES-induced muscle fatigue. Here we describe the design and assessment of the FES exercising platform, comprising a controllable multi-channel electrical stimulator and an instrumented standing frame. The platform supports standing and postural shifting, provides real-time human-in-the-loop FES control with on-line feedback to the user. The platforms is used to investigate the effect of regular exercise on the distribution of BMD in people with paraplegia.

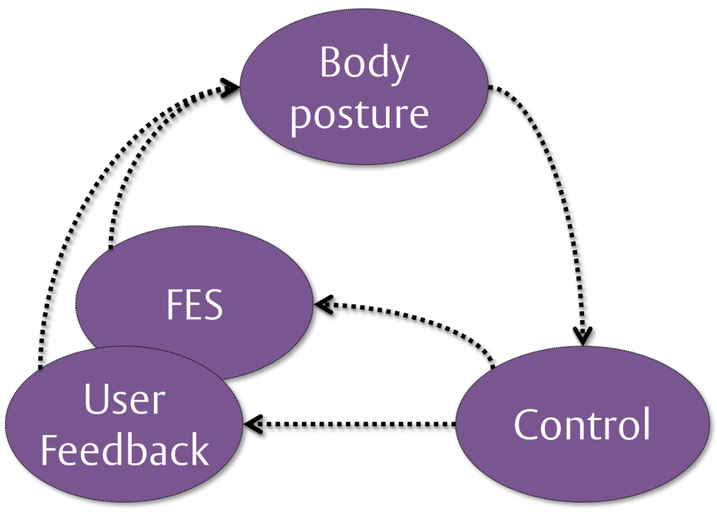
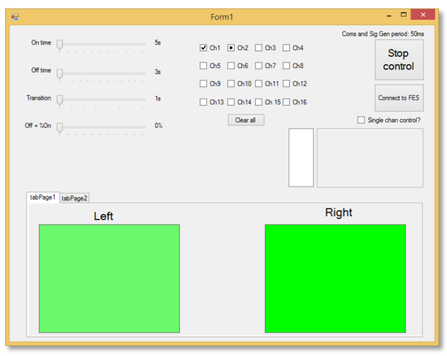


Figure 1: System design of FES exercise platform. The user's body posture as captured by mocap and force sensors is fed to the control system . In turn the control activates FES channels and provides user feedback which changes the user's body posture, with an aim to achieve the required exercise routine .

Methods

The FES exercising platform comprises a metal frame with support bars and a safety harness, two 3-axis load-cell assemblies, two 6-axis force plates for accurate force measurement, and a custom-made 16 channel FES stimulator (Fig. 3, left). Furthermore, body motion capture data are recorded with a Qualisys mocap system. Aggregated information from all the sensors is synchronised, and processed in real-time for two purposes: (i) to automatically control the output of the FES stimulator, and (ii) to provide compelling visual feedback to the participant for exercising instructions and performance monitoring (Fig. 1).



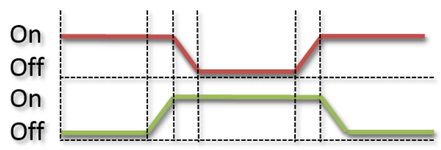


Figure 2: FES control and visualisation.. Left) Control panel for the 16 channel FES with posture shifting visualisation. Right) Posture shifting channel pattern from left to right side. On, Off, and transition periods as well as On/OFF FES amplitude are all controllable variables.

Results

The FES exercising platform allows automated safe standing and exercising for people with paraplegia. It can be used for long-term investigation of the effects of various types of exercises on BMD. By using body posture and force data, the system decreased muscle fatigue by activating only the muscles required to maintain standing, at any given time. The performance feedback, increases participant engagement and makes it easier to meet exercise targets. In pilot testing of the platform we achieved posture shifting exercising of up to 30 minutes, with minimal forces recorded from hand support (< 3kg) .

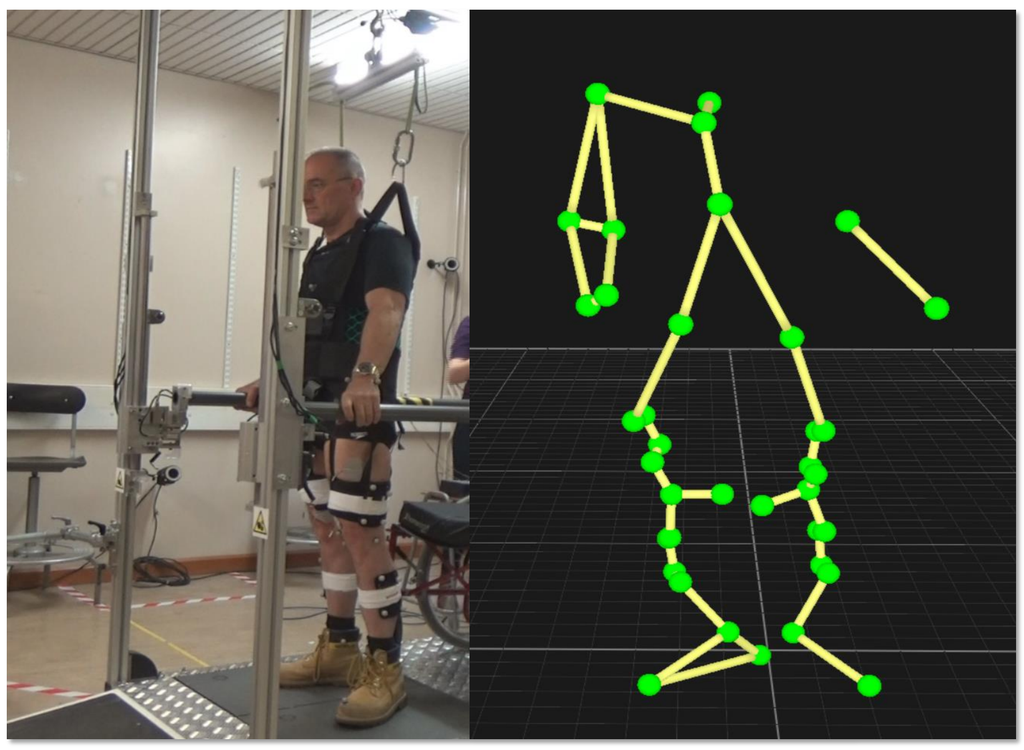


Figure 3: Active standing with FES on the exercising platform. Left) A participant with paraplegia standing in the exercise platform. The participant is performing posture shifting exercises, with Right) Simultaneous mocap recording to estimate posture.

Discussion & Conclusions

The FES exercising platform aids the study of techniques for improving BMD through FES intervention. The platform offers prolonged and engaging exercising routines, and provides a wide range of postural measurements for assessment of exercising performance.

To improve the system we are currently towards:

a) An excergame design for multimodal feedback and rewards to the users.

b) A reduced set of markers for posture estimation to achieve robust control and shorter set-up times.

c) A joint based control for recruiting additional muscles groups and allowing more complex exercise postures

References

1. R. K. Shields, S. Dudley-Javoroski Musculoskeletal Plasticity After Acute Spinal Cord Injury: Effects of Long-Term Neuromuscular Electrical Stimulation Training Journal of Neurophysiology Apr 2006, 95 (4) 2380-2390; DOI: 10.1152/jn.01181.200
2. Krajl, A., Bajd, T., Turk, R., & Benko, H.. Posture switching for prolonging functional electrical stimulation standing in paraplegic patients. Paraplegia, 1986, 24(4), 221–230. JOUR. Retrieved from http://dx.doi.org/10.1038/sc.1986.31

Funding

- Supported by EPSRC

Contact information

- School of Biological Sciences, University of Reading, Whiteknights, RG6 6AY
- Email: ioannis.zoulias@reading.ac.uk | w.holderbaum@reading.ac.uk
- Website: www.fesreading.uk