Motor Unit Synergies and Clusters during Isometric Contraction in Individuals with Spinal Cord Injury

Zhihao Duan[1], Asta Kizyte[1], Emelie Butler Forslund[2,3], Elena M. Gutierrez-Farewik[1,4], Pawel Herman[5], Ruoli Wang[1]
[1]KTH MoveAbility, Dept. Engineering Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
[2] Department of Neurobiology, Care Science and Society, Karolinska Institutet, Stockholm, Sweden
[3] Aleris Rehab Station R&D Unit, Solna, Sweden
[4] Department of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden
[5] Division of Computational Science and Technology, Electrical Engineering and Computer Science, KTH Royal Institute of Technology and Digital Futures, Stockholm, Sweden
Email: ruoli@kth.se

Summary

This study investigated motor unit (MU) synergies and clustering in the soleus (SOL) and gastrocnemius medialis (GM) muscles during isometric plantarflexion in persons after spinal cord injury (SCI). The results revealed notable differences compared to controls, particularly in the distribution of MU clusters at low contraction levels. A reduced proportion of MUs in the shared cluster was observed, indicating disrupted synergies. These disruptions likely contributed to impaired muscle coordination and force steadiness, as reflected by higher root mean square error (RMSE) in the SCI group. The findings provide valuable insights into the neural adaptations associated with SCI and future rehabilitation strategies development.

Introduction

Previous studies have highlighted the importance of muscle synergies in coordinating motor tasks and their alternations following SCI. However, adaptations in muscle synergy patterns at the MU level after SCI remains largely unexplored. This study aims to investigate MU synergies and clustering between SOL and GM muscles during isometric plantarflexion and to explore whether differences can be observed in persons with SCI.

Methods

Fifteen subjects with SCI (10 male, age: 54.9±13.6 yrs, BMI: 25.9±4.5) and eight non-disabled subjects (5 male, age: 50.6±13.3 yrs, BMI:24.3±5.2) performed isometric plantarflexion tasks at 20% and 50% of their maximum voluntary contraction (MVC) following a trapezoidal torque profile. High-density electromyography (HD-EMG) signals from the SOL and GM, along with the ankle torque, were collected. The HD-EMG signals were decomposed into MU spike trains using the convolutional kernel compensation algorithm [1]. The discharge times of MUs from the SOL and GM were filtered and pooled. Fact analysis was applied to identify two primary muscle modes [2]. Correlations between filtered MU discharge times and identified muscle modes were then calculated. Finally, MUs were classified into three clusters - GM, SOL, and shared - based on their correlation with muscle modes: MUs with a ≥ 50% correlation to GM or SOL modes were assigned to the respective clusters, while those showing similar correlations to both modes were categorized as shared. The proportions of each cluster within each muscle were calculated. The RMSE between measured and target ankle torque was calculated to evaluate the performance of the torque tracking. Inter-group differences in the cluster proportions were analyzed using a linear mixed-effects model, while performance of the torque tracking using an independent samples t-test (significance level: $p < 0.05$). Ethical approval was obtained from the Swedish Ethical Review Authority (2020-02311).

Results and Discussion

The results showed that the distribution of MU clusters was significantly affected following SCI at a low contraction level (Figure 1B). Specifically, the proportion of MUs in the shared cluster was significantly reduced, indicating disrupted synergies between MUs in these muscles. This disruption likely contributes to impaired muscle coordination and reduced force steadiness, as reflected by the higher RMSE in the SCI group (Figure 1A).

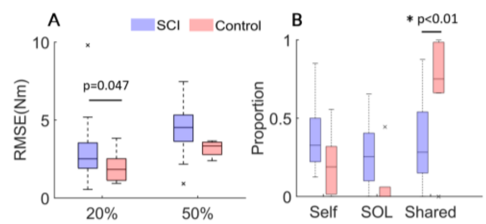

Figure 1: (A) RMSE between measured and targeted torque at 20% and 50% MVCs. (B) MU clusters in the GM at 20% MVC.

Conclusions

This study revealed the MU synergies and clustering in the SOL and GM muscles, with a reduced proportion of shared MUs observed in individuals with SCI. These findings offer valuable insights into muscle synergies and neural adaptations following SCI, providing essential information for developing future rehabilitation strategies.

Acknowledgments

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References

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