Personalized Upper Limb Musculoskeletal Models for Persons with Cervical Spinal Cord Injury Based on Clinical Functional Tests: A Computational Study

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Summary

Personalizing musculoskeletal (MSK) models for persons with disabilities is challenging in rehabilitation applications. Current approaches rely on data collection using specific equipment, leading to high costs and limited practicality. This study proposes a new MSK model for persons with cervical spinal cord injury (CSCI), personalized through physical function tests in clinical settings. The proposed model successfully simulated upper-limb movements across six classifications of CSCI. Our method contributes to model-based evaluation of assistive technologies and supports the development of MSK models for other disabilities.

Introduction

Musculoskeletal (MSK) modeling faces challenges in accurately reflecting the physical dysfunctions of persons with disabilities. While previous studies have proposed MSK models representing disabilities [1][2], they rely on data collection using specialized equipment, such as medical imaging and biomechanical data, leading to high costs and limited applicability in rehabilitation. In the present study, a new personalized MSK model based on clinical functional tests is proposed. An upper-limb MSK model is developed for persons with cervical spinal cord injury (CSCI), whose personal differences are easily captured due to significant variations in physical functions depending on the classification of impairments.

Methods

The proposed MSK model reflects physical dysfunctions, such as muscle strength weakness and joint contractures, based on data from manual muscle tests, range of motion tests, and 3D scanning for a participant with CSCI. This approach enables simple data collection for modeling. We first constructed upper-limb MSK models with muscle strength weakness corresponding to six classifications of CSCI (C6B3, C6B2, C6B1, C6A, C5B, and C5A) [3], and simulated lateral raising motion of the upper limb for each model.

Results and Discussion

The C6A and C5B models exhibited significant elbow or wrist flexion during the lateral raising simulation, as shown in Fig. 1. Dysfunction of the elbow and wrist extensors prevented the maintenance of an extended posture against gravity. Thus, the proposed model successfully simulated upper-limb movements across different CSCI classifications. Our method contributes to model-based evaluation of assistive technologies and supports MSK model development for other disabilities. We are currently conducting an experimental study with actual participants with CSCI.

Conclusions

The proposed MSK model successfully reproduced upper-limb function for each CSCI classification. Our method contributes to the application of assistive technologies and the development of MSK models for persons with disabilities.

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References

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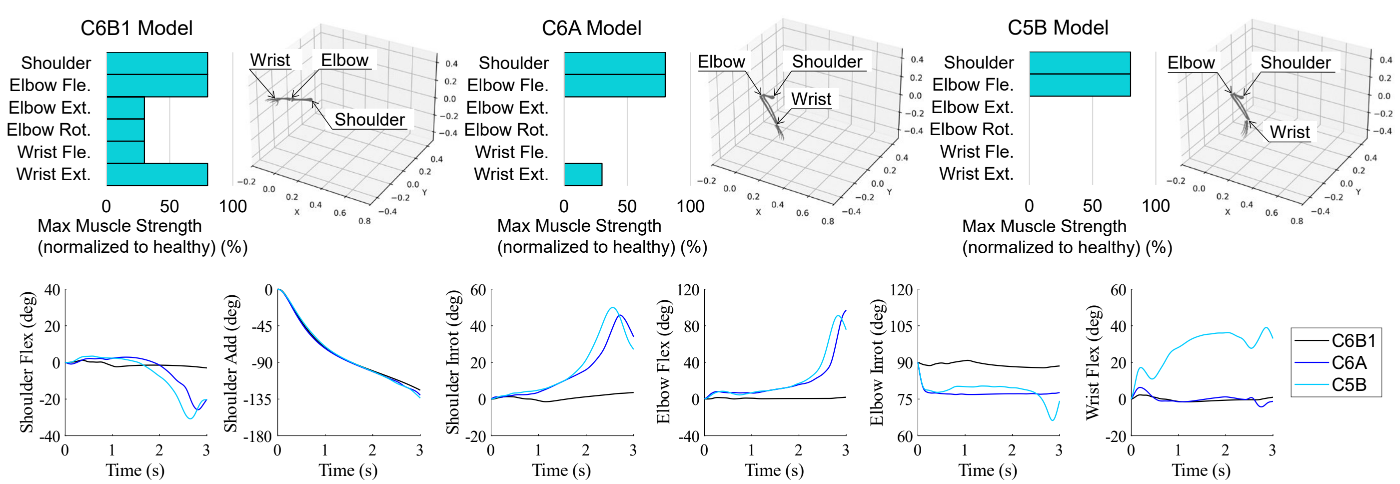

Figure 1: Simulation results for models with C6B1, C6A, and C5B classifications of CSCI (top) and joint angles during the simulation (bottom).