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論　文　要　旨
Thesis Abstract

（yyyy/mm/dd）2022 年　09 月　09　日

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主論文題名　（Title）

Evaluation of Upper Limb Muscle Activation Using Musculoskeletal Model with Rehabilitation Assistive Device

内容の要旨　（Abstract）

The number of stroke survivors in this world is quite large, and most of these survivors experience impairment impact on the upper limb function. Patients who suffer from upper limb impairment usually have difficulty performing daily activities that require using the upper limb, such as feeding, washing, etc. Some patients may recover some functionality of the upper limb function following the rehabilitation. The recovery of arm movements is one of the most important goals during stroke rehabilitation to avoid long-term disability that may restrict daily living activities (ADL), social and occupational activities that can lead to depression.

In order to regain the function of motor skills, many rehabilitation approaches are proven and being used widely such as locomotor training which uses task-specific and repetitive training such as using the treadmill to perform tasks repetitively. With recent advanced technologies, there is a lot of interest in using robots and wearable devices for rehab purposes. An assistive device that applies forces to the body to assist with motor tasks is one approach that may assist people with upper limb disorder or prevent injury as well as improve task economy. Recent studies show that mechanically cable-driven devices which are more affordable and suitable for use around the home could affect muscle activation during the tasks to help with rehabilitation, especially for the upper limb. Many of these wearable passive devices are designed to support and give assistance to assist the upper arm movement for the static task. However, the effect of the assistive force on the muscle output was not widely investigated and it is unclear whether this device built for static tasks would be suitable for supporting dynamic arm movements, which include activities of daily living and rehabilitation exercises.

Wearable devices are systems that are in close contact with the human body. Thus,

their performances are influenced by many factors. It also offers numerous challenges to its design, evaluation, and modification including difficulty analyzing the effectiveness of the device and discovering the effect of changes in parameters on human muscle behavior. Therefore, numerical simulations play an important role in solving these challenges and have the potential to improve treatment strategies and medical decision-making.

In this study, the work focuses on the evaluation of upper limb muscle activities using a developed human-device model has been carried out. A human-device model is developed and this model is further validated and used in biomechanical software OpenSim to simulate the effect of the assistive device on the upper limb motion. An experimental protocol consisting of a series of motions was executed with five healthy subjects. Muscle activation on the brachioradialis, biceps, and triceps muscles was measured by using surface electromyography (EMG) and analyzed. The simulations with a human-device model to estimate muscle output were performed for three tasks. The desired assistive force is translated to the arm joint along with a tendon routing structure. Assisting movement by the wearable device was evaluated by measuring muscle activation with-assist and without-assist conditions.

Results showed that a musculoskeletal model with and without an integrated assistive device could produce muscle activation patterns more similar to the EMG measured for all muscles of interest during the simulated upper dynamic tasks. The human-device model results show that muscle force values for two primary arm muscles (Biceps and Brachioradialis) were reduced during the simulated task when wearing the assistive device. These results are congruent with expectations, with the assistive device that supports the upper limb movement, providing practical assistance. In addition, the group data were tested for differences using statistical analysis Wilcoxon signed-rank test reveals main activated muscles brachioradialis and biceps muscle shows differences in measured data when comparing the subject with and without wearing the device.

A comparison of measured EMG muscle data and human-device models revealed that, although the model did not fully incorporate similar muscle physiology completely, muscle force generated from the biomechanical simulation is comparable with measured muscle activity from the experimental. The results of this study contributed to the importance of evaluating muscle output using the biomechanical simulation, which could reduce the resource-intensive and time consumed with the experimental testing.

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