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Research Article

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

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In recent years, wearable assistive device has been used to support upper arm movement training for rehabilitation purposes. A wearable assistive device could affect the muscle output during motor tasks to support upper limb disorder rehabilitation training. However, the investigation of muscle activity with the given assistive force is not widely investigated. In this study, the evaluation of upper limb muscle activities using musculoskeletal simulation systems with the developed wearable cable-driven assistive device has been carried out. 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 musculoskeletal model to estimate muscle output with and without a wearable assistive device were performed for three tasks. An assistive upper arm device was integrated into the musculoskeletal model, and 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. The results show that the use of the wearable assistive device can effectively assist in arm movement. Comparisons of measured EMG muscle data and the musculoskeletal model revealed that muscle force was generated throughout the arm. The integrated musculoskeletal model results show that muscle force values for two primary 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. The results highlight the importance of evaluating muscle output for the developed wearable assistive device to support the assistive movement. Lastly, the musculoskeletal simulation system could reduce the resource-intensive, and time consumed with the experimental testing could be achieved.

1. Introduction

In the past years, in many areas, assistive devices have been developed to support humans in performing different types of tasks and support activity of daily life. Assistive devices have also been developed in the medical or rehabilitation field. These devices treat or support patients in case of loss of function caused by diseases, especially stroke patients.

Stroke often causes permanent and complex long-term disability in adults, reducing the patients' quality of life and bringing enormous pain to their physiology and psychology and burdening families in general [1, 2]. In literature, upper limb hemiparesis is widely reported as one of the primary impairments after stroke. While many patients recover ambulatory function after dense hemiplegia, arm motor skills restoration is often incomplete. More than 60% of patients cannot use their paretic hands in functional activities [3]. The recovery of arm movements is one of the most important goals during stroke rehabilitation to avoid long-term disability that may restrict activities of daily living (ADL) and social and occupational activities and lead to depression.

Effective rehabilitation training can improve patients' nerve function and maintain the degree of joint activity to help the patient gain their upper limb function capability. Traditional rehabilitation training is a one-to-one auxiliary exercise for patients by therapists. This method is challenging to develop an effective treatment plan, and it is tough