A simulation model of FES for restoring hand grasp in hemiplegia

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Abstract

Purpose: To develop a musculo-skeletal dynamic model for simulating hand grasp by means of FES in paretic hand.

Methods: The skeletal model, which consisted of humerus, radius, ulna and bones of hand, was developed from CT data of. The muscle model, which had been designed by Hase, was developed about flexor carpi ulnaris, flexor carpi radialis, extensor carpi ulnaris, extensor carpi radialis longus and brevis. These muscles had the physical properties that were different from muscle to muscle. In this study, the properties were obtained from the study written by Gregory et al. We installed the muscle model into the skeletal model on the three-dimensional analysis software “Visual Nastran”. Except the wrist joint, the other joints were fixed in this model. We controlled the model by using the numerical analysis software “MATLAB”.

Results: We stimulated the extensors with muscle activator 0.4. We could confirm extension of the wrist.

Conclusion: The wrist extension on the model suggested the tenodesis grasp in hemiplegic hand.

1. INTRODUCTION

Approximately half of all stroke survivors are left with major functional problems in their hand and arm [1]. Hand splinting, plastering and exercise therapies have been used to treat paretic hands, however, the best methods of treatment remain uncertain. Recently, functional electrical stimulation (FES) has been applied for restoring hand grasp, since Rebersek et al has used FES to restore hand grasp in 1973 [2]. And many studies have supported the efficacy of FES [3]. However, it is difficult to know that the success or failure of the restoration or the grasping strength of hand grasp before the surgery. The purpose of this study is to develop a musculo-skeletal dynamic model for simulating hand grasp by means of FES in paretic hand.

2. METHODS

2.1. Development of skeletal model

A humerus, radius, ulna, carpal bones, metacarpal bones and phalanges were obtained from a skeleton. The bones of the skeleton were scanned by CT, and these data were converted into three-dimensional skeletal model on the three-dimensional design software “MIMICS” (figure 1). The position of wrist was set in neutral flexion and deviation, and the elbow was set in 45° flexion and full pronation.

Figure 1: Skeletal model on MIMICS

2.2. Development of muscle model

Muscle model, which had been designed by Hase [4], was developed by the numerical analysis software “MATLAB” (figure 2). This model demonstrated the dynamic characteristic of muscles such as length-tension relationship and force-velocity relationship in numerical formulas. It consisted of a contractile element which generated muscle tonus optionally, and 3 elastic elements (series elastic element, parallel elastic element and tendon) which generated muscle tonus.
passively. These elements had the physical properties that were different from muscle to muscle. In this study, these properties were obtained from the study written by Loren GJ et al [5].

Another muscle model was developed by the three-dimensional analysis software “Visual Nastran” (figure 3). A muscle tonus, which was generated in the muscle model developed by “MATLAB”, was transmitted to the skeletal model through this muscle model. This model consisted of an actuator which the muscle tonus was transmitted to, strings which could not expand or contract and connected the origin with insertion, and globules which expressed muscle curve and thickness.

2.3. Control of musculo-skeletal model

Once we input a muscle activation which assumed a stimulation of FES into one of muscles, a muscle tonus was generated in the muscle model on “MATLAB”. The muscle tonus was transmitted to the muscle model on Visual Nastran. Motions of skeletal model occurred with contraction of the actuator and changed not only a length and a contraction velocity of the stimulated muscle, but also those of the other muscles. The changes of length and contraction velocity of the muscles fed back to the muscle model on “MATLAB”, and new muscle tonuses were generated in each muscle. We controlled the musculo-skeletal model by turning this circuit (figure 4).

3. RESULTS

We set up muscle activation with 0.4, and stimulated the wrist extensors. As a result of simulation, we could confirm that the wrist extended to drosiflexion from neutral position.

4. DISCUSSION AND CONCLUSIONS

Dynamic tenodesis is an effect that is used as a substitute to proper, finger-flexing grasp. It is made possibly by the anatomy of the hand. When the human wrist is flexed, the fingers naturally fall into a position of extension and thumb into a position of abduction. Alternately, when the wrist is dorsiflexed, the fingers naturally fall into a position of flexion and the thumb into opposition with the index finger. Therefore, we believe it proves tenodesis grasp occurs in paretic hand that the dorsiflexion was confirmed in this model. However, of course we need further study to simulate fingers motion in order to measure the strength of flexion and opposition.

References