ESTIMATION OF CHANGING MUSCLE ACTIVATION PATTERNS TO ACHIEVE A SPECIFIC JOINT MOMENT PROFILE

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INTRODUCTION

EMG biofeedback training has been used among individual muscles of patients with neurological disorders (Wolf, 2001). Since the muscles of these patients are inappropriately activated, it is important to know how much activity should be added or reduced during muscle training. In this preliminary study, we have created a biomechanical model to estimate the corrective changes in muscle activation patterns that would enable a subject to achieve a new joint moment profile during walking.

METHODS

A forward dynamics model was developed based on a Hill-type muscle model (Buchanan et al., 2004). The electromyographic (EMG) and kinematic data were used to calculate the joint moments. Inverse dynamics was also used to calculate the joint moments for comparison. An optimization algorithm was then employed, and the parameters in the forward dynamics model were adjusted or *tuned* to minimize the difference between the forward and inverse dynamic joint moments. Once the parameters were tuned, the model could then be used to predict joint moments for new muscle activation patterns.

Using the tuned forward dynamics model, we constructed an optimization model using constrained simulated annealing (Wah and Chen, 2000). Different cost functions were used for different joint moment profiles. The new EMG pattern was optimized to minimize the cost function so that it may achieve the new joint moment profile. The new EMG should be in the range of [0, 1]. In this paper, “EMG” connotes the normalized, rectified and filtered EMG. Ankle joint and knee joint were treated separately in this model.

RESULTS AND DISCUSSION

Data were collected from one healthy subject’s walking trials, including the EMGs from major muscles, joint positions, and force plate data. Maximum voluntary contraction trials were collected for the normalization of EMG. In this paper we use the ankle joint as an example. We included the four main muscles: tibialis anterior (TA), medial and lateral gastrocnemius (GM and GL), and soleus (Sol). The data of interest are from heel-strike to toe-off.

Firstly, the forward dynamics model was tuned using the subject’s gait trial. The tuned forward dynamics model predicted the ankle joint moment well, as shown in Figure 1. Through the comparison of calculated joint moment from original EMG with inverse dynamic joint moment, we found that the R^2 value was 0.928, root mean square (RMS) error was 5.98 N·m, and the average stress cubed per muscle was 64561.4 N^3/cm^6.

The new EMG patterns were then calculated through the optimization model. Here we show the results using the sum of muscle stresses cubed as a cost function (Crownshield and Brand, 1981). We kept the joint moment and kinematics unchanged, and the EMGs of the four muscles were altered individually. The calculated joint moment from the new EMG was also compared with the inverse dynamic joint moment, as shown in Figure 1. The R^2 value was 0.965, RMS error was 2.85 N·m, and the average stress cubed per muscle was 6676.3 N^3/cm^6. With the new EMG patterns, the sum of stresses cubed was greatly reduced.

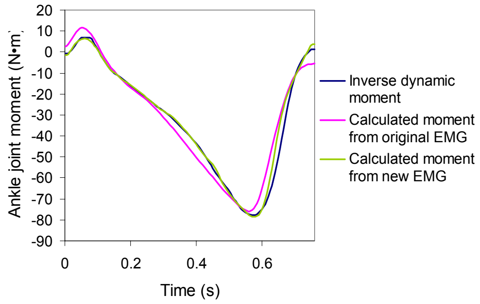

Figure 1: The ankle joint moment patterns

Figure 2 shows the calculated ΔEMG patterns. As a part of a rehabilitation protocol, a subject could increase his EMG through functional electrical stimulation or decrease his EMG through biofeedback training (of course, biofeedback training could be used to increase muscle activity as well).

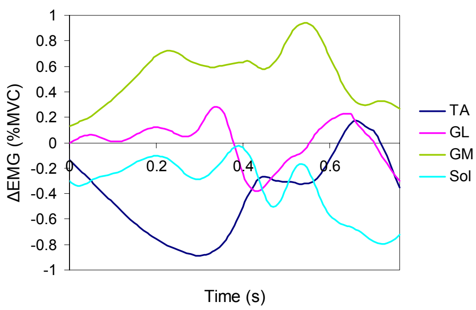

Figure 2: The change of EMG patterns

Figure 3 shows the calculated muscle forces from the original and new EMG. Note that in the original gait trial, the soleus was highly activated, producing much bigger force than gastrocnemius; while in the new gait trial, the soleus force was reduced, and gastrocnemius forces were increased. With the forces distributed evenly across the plantarflexors, decreases in fatigue and lower muscle activations might be expected.

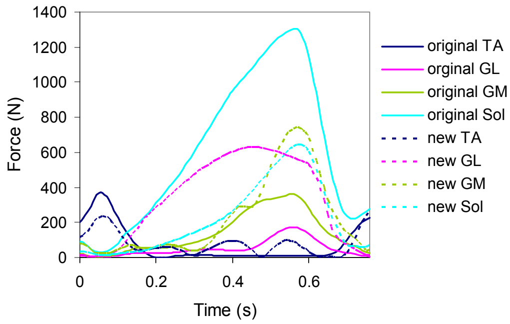

Figure 3: The calculated muscle forces with the original and new EMG patterns

SUMMARY/CONCLUSIONS

Through this modeling work, we determined changes in muscle activation patterns for the subject that would decrease the sum of muscle stresses cubed. This approach to optimize muscle activity could be used in the rehabilitation of patients with neurological disorders to achieve specific joint moment profiles.

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