AN EVALUATION OF MUSCLE MODEL PARAMETERS DETERMINED BY AN OPTIMAL FIT TO A STATIC STRENGTH CURVE

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INTRODUCTION

For musculo-skeletal simulation the determination of model parameters is an important step. In order to characterize the muscular portion of the simulation model, several parameters must be determined. To determine muscle's static moment producing capability, it is necessary to know for each of the contributing muscles: degree of activation, moment arm, fiber length, tendon length, and the force-length properties.

Hatze (1981) presented a technique to determine the value of several of these parameters when given joint moments for a range of joint angles. Such an approach is attractive, particularly if a subject specific model is to be developed. However, to the best of our knowledge a careful evaluation of this method has never been performed. The purpose of this study was to determine the effectiveness of this approach in reproducing joint moment profiles of individual muscles.

PROCEDURES

The three major elbow flexors were chosen to evaluate the technique. Two different muscle models were developed. The first model was used to produce theoretical data where the individual muscle moment profiles were known. Given the data from the first model, parameters were determined for the second model.

Model one consisted of the force-length model of Hatze (1981), and a non-linear model spring representing the tendon. The parameters for the three muscles in model one were obtained from the literature (Hatze, 1981; Challis and Kerwin (1994). The muscle lengths were taken from van Zuylen (1988), and the moment arms were from Pigeon (1996).

Model one was then used to produce moment-angle curves for each of the three modeled muscles. The data were then summed to produce the net moment-angle curve for the elbow. To make the data more realistic random error was then added to this data. The distribution of random errors was estimated from a series of maximum efforts obtained from four subjects over the course of several weeks.

Given the noisy data from model one the task was to estimate the parameters for model two. To do this a static optimization algorithm was used, where the task was to find the muscle model parameters for model two so that a good fit was obtained to the moment-angle curve produced by model one. Multiple seeding of initial parameters estimates were required to guarantee optimization convergence.

The second model differed from the first in that the tendons in the second model were assumed to have a linear stress-strain curve, and a different model of the force-length curves of the fibers was used.

The net joint moment and the individual muscles moment-angle curves from model one were compared with those estimated by model two. The comparisons were numerically quantified using percentage root mean squared difference (%RMSD).

RESULTS

The model was able to fit the total moment angle curve very well. Typically %RMSD was less than one percent. The individual moment angle curves varied between two and 35 percent. Figure 1 shows a typical set of fits.

DISCUSSION

The evaluations run assumed that the moment arms and muscle lengths were known for each of the elbow flexors. It was also assumed that the maximum isometric forces were known. Although this may not seem realistic, all of the variables can be determined from MRI.

The evaluation used two different muscle models to evaluate the technique for determining model parameters. This approach is required because there is no other source of criterion data. This evaluation could be considered a best case scenario.

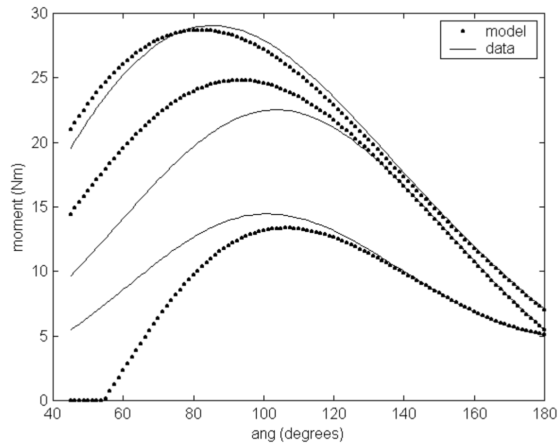

Figure 1: Top - biceps 2.6 %RMSD. Middle - brachialis 17.3 %RMSD. Bottom - brachioradialis 27.6 %RMSD.

Using optimization to determine muscle model parameters can accurately reproduce the total joint strength curve. In many investigations this may be sufficient. However, some cases, such as the modeling of surgical interventions, require the role of individual muscles to be determined. This technique can be fairly effective in these applications if the number of parameters to be determined is kept to a minimum.

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