MUSCULOSKELETAL PARAMETER VARIABILITY EXPLAINS VARIABILITY IN ELBOW FLEXION STRENGTH DEFICIT DUE TO LONG HEAD BICEPS TEAR: A STOCHASTIC MODEL

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INTRODUCTION

Rupture of the Long Head of Biceps tendon (LHB) results in varying elbow flexion strength deficit (mean deficit: 8%, S.D. 12% of mean) (Mariani et al. 1988). This variability in strength is interesting because it is previously unexplained. Observations of musculoskeletal parameters also exhibit variability (Murray et al. 2000). We hypothesize that the variation in elbow flexion strength in healthy normals and in subjects with LHB rupture is explainable via variability in musculoskeletal parameters, specifically muscle physiologic cross sectional areas (PCSA), moment arms and optimal muscle lengths (OML) of elbow flexors. The purpose of this research was to use a stochastic model to predict the median and distribution of maximum isometric elbow flexor muscle forces when modeling PCSAs, moment arms, and OMLs as random variates.

METHODS

A Monte Carlo model was used to stochastically simulate the effects of variability in PCSAs, moment arms, and OMLs on elbow flexion strength. Data in the literature was used to construct gamma distributions (Law and Kelton, 2000) for the following parameters: measured elbow flexion torque (Askew et al. 1987, Mariani et al. 1988), PCSAs and moment arms (Murray et al. 2000), and OMLs (Chang et al. 1999). Parameters sampled from these distributions were input to a biomechanical model to predict muscle forces and flexion torque. The simulation was conducted for the healthy normal (No-tear) case and the LHB rupture (Tear) case. The work consisted of three phases: model validation, muscle specific tension prediction, and muscle force prediction.

As is commonly done in discrete event simulation (Law and Kelton, 2000), model validation consisted of adjusting model parameters to match model predictions to empirical measurements. One hundred distributions, each consisting of 10000 samples, of predicted and measured torque were constructed. For each case predicted and measured torque distributions were compared by forming 95% confidence intervals (C.I.) for the difference in means, and ratio of standard deviations. Standard deviations for PCSA and OML were iteratively increased (No-tear) and decreased (Tear) until the C.I. for the difference in means included 0 N-m and the C.I. for the ratio of standard deviations included unity. This process also drastically reduced RMS error between the measured and predicted torque distributions. With these parameter sets, predicted and measured torque distributions were equivalent.

Next, for the No-Tear case, 5000 samples were made from each parameter distribution to construct a predicted flexion torque
distribution. Specific tension was determined by minimizing RMS error between the predicted torque distribution and a distribution of 5000 measured flexion torques. Specific tension was assumed equal between the two cases.

Specific tension was then used to predict muscle force distributions for another 5000 iterations of the simulation for the No Tear and Tear cases (Chang et al. 2000), respectively.

RESULTS AND DISCUSSION

The validation and specific tension phases resulted in RMS error between measured and predicted torques of 50 N-cm (Fig 1) for both the Tear and No-Tear cases. Specific tension was 140 MPa. Predicted muscle forces are shown in Table 1.

This model is not deterministic and therefore affords an examination of how variability in parameters affecting muscle force and torque can predict variance in strength in LHB rupture subjects and healthy normals. Limitations include a lack of an EMG-Activation model, i.e. assuming 100% muscle activation for maximum isometric contractions, and the assumption of equal specific tension for the two cases. Additionally there is no consideration of parameter covariance.

SUMMARY

This study furthers our understanding of effects of parameter variability on variability in muscle force and elbow flexion strength. Variability in elbow flexion strength is explainable via variability in musculoskeletal parameters. Differences in the variability of the measured torque between the two cases are explained by differences in PCSA and OML variability.

REFERENCES


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**Figure 1:** Probability distribution of measured and predicted flexion torque.

| Table 1: Predicted elbow flexor muscle forces [Newtons] (median and S.D.) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Biceps LH       | Biceps SH       | Brachialis      | Brachioradialis |
| **No Tear**     | 406.1 (195.0)   | 353.9 (106.6)   | 928.4 (240.4)   | 86.1 (100.5)    |
| **Tear**        | 474.4 (63.8)    | 1220.0 (140.8)  | 140.9 (71.4)    |