NEURAL NETWORK ESTIMATION OF ISOKINETIC KNEE TORQUE

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INTRODUCTION

Rectified, low-pass filtered electromyography (EMG) has been used with Hill-based musculoskeletal models to estimate muscle force and joint moments (Hof & Van Der Berg, 1981). However, it is rather difficult to find a set of neuromuscular activation signals that, when input into such models, produce coordinated movement simulation (Zajac, 1993). This may be due in part to a non-linear response of muscle tissue to activation. Recently, artificial neural network (ANN) models have been used effectively to estimate joint torque in the elbow (Luh et al., 1999; Wang & Buchanan, 2002), but no studies have utilized ANN theory in prediction of lower extremity torque. The purpose of this study was to develop an initial model to estimate isokinetic joint torque produced at the knee during concentric and eccentric contractions. It was hypothesized that ANN mapping would accurately estimate knee joint torque. Linear regression was performed for comparison.

METHODS

Ten young adults (6 female / 4 male; 22.9yrs, 173.7cm, 72.3kg) were recruited for this study within the guidelines of the University I.R.B. All participants were determined to be free of neuromuscular or orthopedic pathologies.

Maximal strength data were collected using a KinCom dynamometer (Rehab World, Hixson, TN, USA). Isometric flexor/extensor maxima were measured at 45°. Isokinetic measures were taken through the knee's functional range of motion in a seated position at 30 and 60°/s. At each isokinetic speed, concentric and eccentric contractions were recorded (two each). Each subject was allowed two sub-maximal practice trials for each joint function. Four total cycles were collected for each direction and speed condition. Subjects were verbally encouraged during each trial to promote maximal motivation.

Joint position and velocity were recorded simultaneously with torque data, at 100Hz. Additionally, EMG signals were sampled at 1000Hz from the vastus lateralis and biceps femoris with passive bi-polar surface electrodes using the Myopac Jr. (Run Technologies, Inc., Mission Viejo, CA, USA). EMG signals were bandwidth filtered (10-1,000Hz), full wave rectified and smoothed with a 4^{th} order Butterworth filter (low pass cutoff = 5Hz). Processed EMG signals were then normalized to the maximal isometric activation.

With all acceptable trials compiled, there were 308 total cases entered for analysis. Linear regression was conducted with age, gender, height, weight, EMG (agonist, antagonist), joint position and velocity as independent variables, and joint torque as the dependent variable. The same inputs were entered into a three-layer back-propagation ANN, with the following settings: training proportion = 0.7, training error goal (E) = 0.1, and hidden units (H) = 5,10,15,20. A bootstrap re-sampling method (50 attempts) assessed each setting of hidden units. Model accuracies were compared using the R-values of each technique.

RESULTS AND DISCUSSION

Linear regression resulted in an R-value of 0.75. Prediction accuracy for the ANN settings reached a maximum of 0.94 (ANN settings: E=0.1; H=10,15,20). Average R-values for those settings were 0.93 (SD, 0.01). The number of epochs needed for solution convergence at those settings averaged from 447.8 (H=20) to 620.2 (H=10). Prediction accuracy was not affected by the number of hidden units, however more hidden units required fewer epochs for convergence (Table 1).

Results indicate that ANN mapping provides a more accurate estimate of knee torque during maximal isokinetic (con/ecc) testing. Performance of the ANN with minimal training (E=0.1) indicates that prediction accuracy is likely without the risk of 'over-training'. Thus, the generality of this system would be more likely to provide accurate estimation for a separate sample of young adults.

CONCLUSIONS

Findings from this initial development of a knee torque prediction model indicate that a more robust estimation of joint torque from muscle activation may be possible using ANN or similar techniques borrowed from the field of computational intelligence. Future efforts will focus on broadening the model to include sub-maximal torque production in more joints and developing adaptive algorithms for estimation of joint moments during locomotion.

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Table 1: Effect of hidden units on accuracy, and time to convergence; Mean ± SD

	H = 5	**H = 10**	**H = 15**	**H = 20**
Prediction Accuracy (R)	0.92 ± 0.01	0.93 ± 0.01	0.93 ± 0.01	0.93 ± 0.01
Time to convergence (Epochs)	978.9 ± 94.2	620.2 ± 262.8	523.8 ± 208.6	447.8 ± 216.7