INTRODUCTION

As an intrinsic risk factor contributing to falls, lower extremity (LE) muscle strength is a critical component in limiting an elderly individual’s dynamic stability (Buchner, 1991; Brown, 1995). Improved functioning in activities of daily living and general mobility have been reported as a result of muscle-strengthening regimens (Buchner, 1991), but no evidence has been presented to indicate which strengthening intervention is most effective (Province, 1995; Wolfson, 1996). Furthermore, no models have attempted to link muscular strength directly to dynamic stability.

In this task, the use of traditional forward dynamics modeling is not warranted as muscular strength changes are initially neuromuscular, rather than structural. Considering the non-linear relationship between individual muscle activation and subsequent joint torque production, and the number of further assumptions made in joint modeling, it is felt that a model is necessary which maps relationships between input and output variables in a non-linear fashion. Artificial neural network (ANN) models are known to be adaptable to variation within a data set, and have shown robust ability to model any function. The purpose of this study was to demonstrate the effectiveness of an ANN model in mapping normalized LE muscular activation levels onto whole body measures of dynamic stability, i.e. mediolateral (M-L) displacement and peak velocity of the center of mass (COM).

METHODS

A three-layer feed-forward neural network was constructed to model the interaction between neuromuscular activation and whole body dynamic stability. A tangential sigmoid activation transfer function was adopted for the hidden layer, and a pure linear transfer function for the output layer. Back-propagated error correction was conducted using the Levenberg-Marquardt algorithm.

The input patterns used to train the network consisted of normalized muscle activation data from the gluteus medius, vastus lateralis and gastrocnemius (medial head) bilaterally, during phases of single and double support (Koshida, 2002). Output target values were given as the M-L displacement of the COM, and the peak M-L velocity of the COM during obstacle crossing (Chou, 2003). These input/output data were selected from a mixed set of previously collected subjects. The subject pool (n=21) consisted of six young adults, ten healthy elderly adults, and five elderly patients with balance disorders.

Input and target data were first normalized to zero mean and unity standard deviation. A training set was then selected randomly from the pool at a given proportion, with the remainder kept as a testing set. After successful training of the ANN, model output was transformed back to real-world units (cm, cm/s), and overall model performance was assessed by regression analysis to detect how well the model estimations fit the target values (R₁ for M-L displacement; R₂, for peak M-L velocity) of the entire subject pool.

The training set proportion (Pr), training error goal (E), and number of hidden units (H) were manipulated to assess which settings provide the best estimation accuracy. With three values for each setting [Pr={0.6, 0.7, 0.8}; E={0.001, 0.0001, 0.00001}; H={5, 10, 20}], a total of 27 setting conditions were tested, with 20 trials each.

RESULTS AND DISCUSSION

Based on the regression analysis, the ANN performed fairly well (mean R-scores ranging from 0.61 to 0.85), considering the limited sample size. For the training proportion condition of 0.6, the ANN achieved moderate accuracy (R₁=0.61, R₂=0.62) when E=0.001 and H=10. When the training proportion was increased to 0.7, accuracy improved (R₁=0.73, R₂=0.64) with E=0.0001 and H=20. Further improvement in accuracy occurred with training proportion set to 0.8 (R₁=0.85, R₂=0.79), E=0.0001 and H=20. More hidden units provided quicker convergence within the model, improving the ability to generalize.

SUMMARY

It appears from this initial assessment that an ANN model is effective in mapping LE muscular activation onto measures of whole body dynamic stability. Further investigation is needed to confirm this stability estimation in a larger, more diverse sample set. Application of this model will eventually allow estimation of an individual’s dynamic stability and lead to predictive outcomes as a result of simulated improvements in muscular strength.

REFERENCES


ACKNOWLEDGEMENTS

This work was supported by the ISB Dissertation Matching Grant and the Oregon Medical Research Foundation.