INTRODUCTION

Traumatic falls in the elderly are prevalent, debilitating and costly. Many studies have attempted falls prediction, with mixed results. Predictive models have included self-reports of imbalance, a history of previous falls, and clinical measures of daily living function, with prediction accuracy reaching 79% (Stalenhoef et al., 2002).

Of those models involving balance control, selection of predictive variables was restricted to static measures of posture (Maki et al., 1994), rather than dynamic measures of musculoskeletal function during activities where balance is challenged. A model that uses measures of muscular challenge, gait function and balance control as input may allow more accurate estimation of falls risk in the elderly.

For this study, neural network theory was selected to develop a model for mapping dynamic measures of gait and balance control onto estimates of falls risk in the individual. The purpose of this study was to test the application of this model in tasks of group categorization and risk estimation.

METHODS

The model consisted of two systems which used in tandem provide a relative distance measure from normal distribution, providing a scaled estimate of risk.

The first system, an artificial neural network (ANN) model, estimated the category of faller / non-faller, based on normalized electromyography (EMG) data from lower extremity muscles (gluteus medius, vastus lateralis, medial gastrocnemius), temporal distance (T-D) measures of gait (gait velocity, stride length, stride time, step width), and medio-lateral motion of the whole body center of mass (COM) during a low-level obstacle crossing condition (2.5% of body height). These measures were previously determined to have some association with balance impairment (Chou et al., 2003).

The ANN was a supervised, 3-layer, feed-forward design with Levenberg-Marquardt error-correction algorithm. Training set proportion was 0.7, randomly selected from a mixed sample of healthy elderly (n=19) and elderly with imbalance (n=10). The output resulted in categorization values between 0 (faller) and 1 (non-faller). The relative operating characteristic (ROC) was used to assess group categorization accuracy (Swets, 1988).

The second system discriminately classified relative risk that an individual would experience falls, based upon output from the first system. The ANN output for each individual case ($X_1$) was compared against a decision line ($X_0$; median value of the healthy sample). If $X_1$ was below $X_0$, it was inferred to be normal. If above $X_0$, the case was examined for its relative distance from
the healthy group. Relative distance ($D_r$) was used as an index for risk estimation:

$$D_r = \frac{1 - x_i}{1 - x_0}$$

Higher values of $D_r$ indicated lower risk of falls, lower values indicated higher risk of experiencing falls.

RESULTS AND DISCUSSION

Group categorization accuracy ranged from ROC values of 0.702 to 0.890. T-D input resulted in higher ROC values (0.848) than EMG (0.733) or COM (0.702). Categorization accuracy improved with the combination of input data types. Best overall accuracy was achieved with a combination of EMG and T-D data (Table 1).

Relative risk estimation using the distance metric $D_r$, produced varied results across the elderly subjects with imbalance, depending upon what types of input data were used to train the ANN. The distance metric values ranged between -1.50 and 1.50, with any values less than -1.00 indicating extremely high risk. When EMG and T-D were combined as input (best ROC value in group categorization), 90% of the individuals with imbalance were estimated to be at high risk of falls ($D_r < 0.20$) and 10% estimated to be at extremely high risk ($D_r < -1.00$).

Group categorization results confirmed the strength of using ANN models to map diverse inputs onto individual-specific outcomes. Accuracy achieved by this model surpassed that of previous studies (89% compared to 79%) which did not use dynamic measures of gait or musculoskeletal function (Stalenhoef et al., 2002). Results from the test of relative risk estimation revealed acceptable delineations of risk level across a variety of subjects with balance impairment.

SUMMARY

In combination, the two tasks evaluated in this study indicate the potential for accurately assessing individuals who may be at risk for experiencing falls; further estimating the severity of that risk, given the current gait function of each individual. If level of impairment is well estimated, many elderly individuals at greater risk of falls might be identified prior to traumatic fall events, thereby reducing the incidence and severity of falls in the elderly population.

REFERENCES


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| Table 1. Accuracy results of the group categorization test. |
|-----------------|-----------------|-----------------|-----------------|
| Input Data Type | Training Goal   | # Hidden Units  | ROC             |
| EMG             | 0.0001          | 20              | 0.733           |
| T-D             | 0.001           | 5               | 0.848           |
| COM             | 0.0001          | 5               | 0.702           |
| EMG, T-D        | 0.001           | 5               | 0.890           |
| EMG, T-D, COM   | 0.001           | 5               | 0.884           |