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Chapter VII

Neural Network Models for Estimation of Balance Control, Detection of Imbalance, and Estimation of Falls Risk

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ABSTRACT

Gait patterns of the elderly are often adjusted to accommodate for reduced function in the balance control system. Recent work has demonstrated the effectiveness of artificial neural network (ANN) modeling in mapping gait measurements onto descriptions of whole body motion during locomotion. Accurate risk assessment is necessary for reducing incidence of falls. Further development of the balance estimation model has been used to test the feasibility of detecting balance impairment using tasks of sample categorization and falls risk estimation. Model design included an ANN and a statistical discrimination method. Sample categorization results reached accuracy of

0.89. Relative risk was frequently assessed at high or very high risk for experiencing falls in a sample of balance impaired older adults. The current model shows potential for detecting balance impairment and estimating falls risk, thereby indicating the need for referral for falls prevention intervention.

INTRODUCTION

In the last 20 years, artificial neural network (ANN) modeling has been used in various applications of disease classification and diagnosis. Recent research has used ANN theory to classify gait patterns (Barton & Lees, 1997; Gioftsos & Grieve, 1995; Holzreiter & Kohle, 1993), estimate dynamic balance control (Hahn, Farley, Lin, & Chou, 2005), and provide diagnostic classification of falls risk (Hahn & Chou, 2005). These most recent efforts have relied on simple three-layer, back-propagation networks and statistical discrimination models. The objective of this chapter is to provide examples of recently successful application of ANN theory in the classification of gait patterns, estimation of dynamic balance control, and diagnostic classification of relative falls risk in the elderly.

BACKGROUND

Traumatic falls in the elderly are prevalent, debilitating and costly, with over 35% of the elderly population experiencing falls (Coogler, 1992) and approximately $20.2 billion spent in treatment each year (American Academy of Orthopaedic Surgeons [AAOS], 1998). Accurate assessment of the risk of falls is critical to reducing the incidence of falls. As humans age, gait patterns are known to adjust, accommodating for reduced function in the balance control system and a general reduction in skeletal muscle strength (Fiatarone and Evans, 1993; Grimby and Saltin, 1983). The temporal-distance (T-D) measures of gait (gait velocity, stride length, stride time, step width) have been used in evaluation of overall function and determination of gait dysfunction in the elderly (Elble, Thomas, Higgins, & Colliver, 1991; Ferrandez, Pailhous, & Durup, 1990; Heitmann, Gossman, Shaddeau, & Jackson, 1989; Judge, Davis, & Ounpuu, 1996; Leiper & Craik, 1991; Maki, 1997; Menz, Lord, & Fitzpatrick, 2003). These studies showed that while T-D measures of gait do provide an overall impression of walking performance, there is substantial inter-subject variability in the measures. Such variability may contribute to a lack of power in accurately predicting the risk of falling in the elderly. The effect of aging on muscle activation and strength in the elderly has been shown to result in higher electromyographic (EMG) signal amplitudes during gait (Finley, Cody, & Finizie, 1969; Shiavi, 1985). However, the resulting force production in aged subjects is highly variable (Galganski, Fuglevand & Enoka, 1993; Grabiner & Enoka, 1995). No previous studies have examined the effect of T-D parameters and EMG activity on control of whole body stability.

Many studies have attempted to predict falls prospectively, with varying results. Previous studies (Maki, Holliday, & Topper, 1994; Topper, Maki, & Holliday, 1993) used measures of static posturography to indicate risk of falls. Results from their work showed that control of medio-lateral sway may be a strong predictor of falls in the elderly. Another