SENSORI-MOTOR DEGENERATION REVEALED BY COP MEASUREMENT – A PILOT STUDY OF DEVELOPING A QUANTITATIVE METHOD

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There are ways of preventing falls. One method is a prediction based on an individual's sensori-motor function. Unfortunately, current methods, based on statistical analyses of data collected across different tests, are contradictory and impractical because of the test diversity. Hence a simple, highly reliable method is desirous from the practitioners' perspective. The purpose of the research was to develop a practical and quantitative way of diagnosing the age-related degeneration of human sensori-motor function in order to predict the potential fallers. The method was based on individual center of pressure (COP) measurement and an artificial neural network (ANN) model, which was built by using the data of 6 young adults and 4 seniors. The study revealed that one could utilize COP and ANN model to predict sensori-motor degeneration related to age.

KEY WORDS: COP, seniors, motor degeneration, FALL, ANN, prediction

INTRODUCTION: The frequency of falls and fall-related injuries increases with age. As the population ages, falls become one of the major health problems, not only for those with some degree of balance or mobility impairment, but also among healthy active seniors (Eagle et al. 1999 & Hill et al. 1999). Thus, as our population ages, falling will continue to increase unless preventative measures are taken. There are many avenues of prevention, such as senior education programs; senior exercise programs; etc. However, one potential method for prevention would be a prediction based on an individual's sensori-motor function. The identification or prediction of potential fallers will help to reduce the frequency of falls among seniors by providing them with an opportunity to reorient themselves in daily activities. It would also ensure that all prevention programs or training courses included the following goals: **a)** recovery of declined sensori-motor function, **b)** prevention of further sensori-motor declination or **c)** slowing of sensori-motor declination.

Unfortunately our current methods of prediction are inadequate for reliable and valid prediction of falls in the elderly. Current methods of prediction are based on the analyses of data collected across different biomechanical tests and are consequently contradictory (Daubney et al. 1999) and impractical (Maki, 1993), because the measurement techniques used are too complicated and too diverse (Hill et al. 1999). Hence, a simple, highly reliable method of prediction is desirous from the practitioners' perspective.

The main reasons for the contradictory results in diagnosing the degeneration of sensori-motor function and fall-prediction in the current research, lie in two characteristics of a biological system -- non-linearity and redundancy, i.e. human sensory afferents are overlapping and somewhat redundant (Rothwell 1994). These lead to the interactions not only among afferents and efferents but also among afferents themselves. The interactions influence the sensori-motor system in three ways, which make accurate predictions very difficult to achieve. These three aspects are: **a)** the integration of the redundant sensory inputs by the central nervous system (CNS), **b)** the re-weighting of redundant afferents (e.g. during & after perturbations) and **c)** the compensatory strategies among intact modalities and declining ones. Because of the complexity of the sensori-motor system, researchers have been attempting to use more parameters from kinematic and kinetic measurements in order to improve the accuracy of predictions. This has increasingly led to the use of impractical prediction tests.

The purpose of this study was to develop a practical and quantitative way for diagnosing the age-related degeneration of human sensori-motor function in order to predict the potential fallers. Contrary to the current methods, this research utilized the ANN model to predict the degeneration of sensori-motor function related to age while keeping the measurement simple.

Only the COP measurement was utilized in the research. It is known that COP measurement captures the excursion of the center of gravity on supporting area during quiet stance and is one of the simplest measurements that can be conducted in biomechanics.

METHODS: The designed method is based on the following facts. Because COP is related to one's involuntary control in quiet stance, it should reflect the CNS integration of sensory inputs from the visual, vestibular and somatosensory systems (Manchester et al. 1989 & Nashner et al. 1979); it should also reveal the re-weighting characteristics after manipulating the vision conditions (Day et al. 1993) or the compensatory strategies after the declination of some sensory function (Panzer et al. 1995). Therefore, excursion length (Fitzgerald et al. 1994), maximum displacement (Suomi et al. 1994), mean, and maximum velocity (Aalto et al. 1988 & Baloh et al. 1994 & 1998) and acceleration (Maki 1993) of COP, can represent the human sensori-motor ability. The redundancy and non-linearity of sensori-motor systems relates these parameters to one another. This relationship looks much like a web. If one point (one parameter) on the web is changed, the others will be changed also. For this reason, researchers encounter difficulties utilizing these parameters as independent variables for predictions.
One suitable tool for capturing the "web-relationship" is the ANN modeling. The basic idea of ANN is the consideration of non-linearity and redundancy. Since ANN is a mathematical abstract of a neural system (Duh et al. 1998 & Landau 1998) and has the ability to capture non-linearity and complex interactions among factors related to the outputs, it possesses the ability to predict the input-output relation of a biological system. Recent studies (Koike et al, 1995) have showed that the ANN model could predict the behavior of a biological system successfully.

Furthermore, experiences show that body weight (BW) and body height (BH) would also influence the net-like interaction of the human sensori-motor system in human activity. These two factors should be considered in the building of the ANN model.

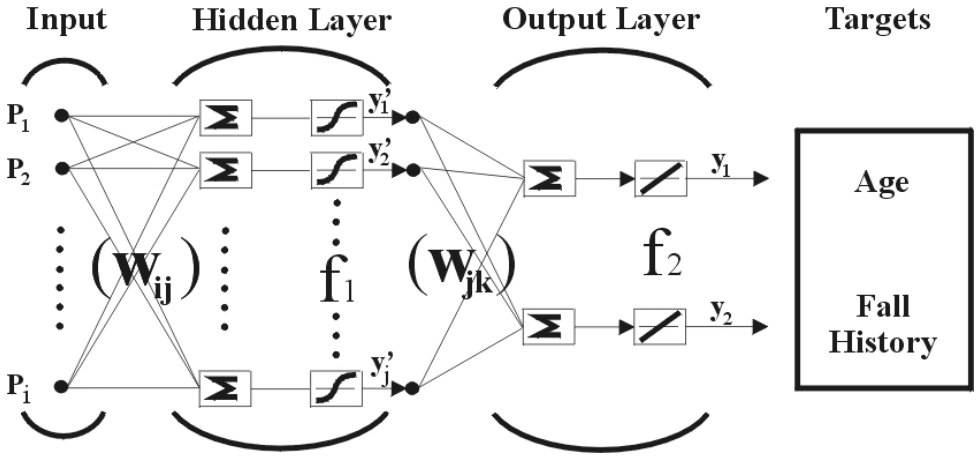

Figure 1 - Design of the ANN model for prediction of fall and sensori-motor degeneration related to age.

Based on the above considerations, an ANN model of 3 layers was established (Figure 1). For capturing the relationship between COP and age-related sensor-motor function, the ANN model had 26 inputs (P_1 to P_i, i=26) in the input layer; 60 non-linear neurons in the hidden layer; and 2 linear neurons in the output layer. The 26 inputs were: BW & BH, length, maximum excursion, mean and maximum velocity as well as acceleration of the COP in the anterior-posterior (a-p) and medial-lateral (m-l) direction with eyes open or closed (BW & BH + 6 parameters $\times$ 2 COP excursions in a-p and m-l direction $\times$ 2 visual conditions = 26 inputs). The two targets were age and fall-history (0 – non faller or 1 – faller).
After ANN training, the first layer weights (W_{ij}) and second layer weights (W_{jk}) were fixed, so that one could use the model and a new measurement to predict the age (output y_1) of the new

subject and fall possibility (output y_2). The predicted age would indicate the declining rate of one's sensor-motor function. For example, if a predicted aged is 65 years for a 60 year old subject, it would mean that the declination of the sensori-motor system of this subject is faster than those individuals whose data are applied to train the ANN model.
Two female groups of subjects were tested in this study: a young group (<22 yrs of age, N=6) and an aged group (>55 yrs of age, N=4). During the test, each subject was asked to stand quietly for 10 seconds, with either eyes open (EO) or closed (EC). The COPs under the feet were measured simultaneously during the stance by an AMTI force plate [USA]. Two more female subjects (21 and 68 years old) were also involved in the test and their data were applied for testing the accuracy of the prediction of the ANN model.

RESULTS: Because there were no fallers in the subjects, the ANN model was only trained by the data of non-fallers. Hence, the prediction of the model at present state is limited on diagnosing the degeneration of sensori-motor function related to age. The prediction results for the two subjects are: 23 for a 21-years old student and 64 for a 68 years old senior.

DISCUSSION: The long term aim of this study is to develop a quantitative method for diagnosing the degeneration of sensori-motor function in order to predict potential fallers. The philosophy of this study was to simplify the present measurements, at the same time to increase the reliability of the prediction. This philosophy would let the outcomes be practitioner-friendly. The primary result reveals that this philosophy has huge potential to reach its final goal. It is clear that the accuracy of the prediction of ANN model depends on the amount of data for ANN training. The more subject data collected, the higher the accuracy. Therefore, a large number subject tests (age from 18 - 65+) and new ANN model training are planned to be done in the near future.
The other potential of the method is to study the influence of different physical exercises on sensori-motor function and to evaluate the training effects. In order to reach this goal, a large number of COP measurements will be needed. The collected data will be grouped. Each group data will be used to establish an ANN model. The grouping criteria could be gender, race and/or participation in regular physical activities (e.g. Tai-Chi). The ANN models based on different group data will be first determined through ANN training. Then, one can enter the same inputs into different predicting models to compare the outputs. The declination of sensory-motor function can be compared amongst groups in the following manner. For example, one could enter the measured data of a Tai-Chi trainee as inputs of the ANN model that has been trained by a normal group, and possibly, obtain a younger prediction than the subject's actual chronological age. The prediction would imply that Tai-Chi slows down the degeneration of sensory-motor function. This knowledge could then be used by government or the health care industry to create preventative fall programs for seniors. Obviously, to reach this goal, a large number (over 500) of subjects should be tested; therefore, a series of researches is being undertaken.

CONCLUSION: This study revealed that one could utilize a simple measurement (COP measurement) and ANN model to predict sensori-motor degeneration related to age.

REFERENCES:
Aalto H, Pyykkö I & Starck J (1988) Computerized posturography, a development of the measuring system. Acta Otolaryngol Suppl, 449:, 71-5.
Baloh RW, Jacobson KM, Enrietto JA, Corona S & Honrubia V (1998) Balance disorders in older persons: quantification with posturography. Otolaryngol Head Neck Surg, 119:1, 89-92.
Daubney M.E., Culham E.G. Lower-extremity muscle force and balance performance in adults aged 65 years and older. Phys Ther, 1999 Dec, 79:12, 1177-85.
Day B.L., Steiger M.J., Thompson P.D., Marsden C.D. Effect of vision and stance width on human body motion when standing: implications for afferent control of lateral sway. J. of Physiology, 1993, 469-99.

Duh M.S., Walker A.M., Ayanian J.Z. Epidemiologic interpretation of artificial neural networks. American journal of epidemiology, 1998, Vol. 147, No.12: 1112-1122.
Eagle D.J., Salama S., Whitman D., Evans L.A., Ho E., Olde J. Comparison of three instruments in predicting accidental falls in selected inpatients in a general teaching hospital. J Gerontol Nurs, 1999 Jul, 25:7, 40-5.
Fitzgerald JE. Murray A. Elliott C. Birchall JP (1994) Comparison of body sway analysis techniques. Assessment with subjects standing on a stable surface. Acta Oto-Laryngologica. 114(2):115-9.
Hill K., Schwarz J., Flicker L., Carroll S. Falls among healthy, community-dwelling, older women: a prospective study of frequency, circumstances, consequences and prediction accuracy. Aust N Z J Public Health, 1999 Feb, 23:1, 41-8.
Koike Y., Kawato M. Estimation of dynamic joint torques and trajectory formation from surface electromyography signals using a neural network model. Biol Cybern, 1995, 73:291-300.
Landau L.J., Taylor J.G. Concepts for neural networks. Springer, 1998, London.
Maki BE (1993) Biomechanical approach to quantifying anticipatory postural adjustments in the elderly. Med Biol Eng Comput, 31:4, 355-62.
Manchester D, Woollacott M, Zederbauer-Hylton N, Marin O (1989) Visual, vestibular and somatosensory contributions to balance control in the older adults. J Gerontol: MED SCI 44(4): M118-127.
Nashner L.M. Organizing and programming of motor activity during postural control. Exp. Brain Res. 1979, 50:177-184.
Panzer V.P., Bandinelli S., Hallett, M. Biomechanical assessment of quiet standing and changes associated with aging. Arch. Phys. Med. Rehabil., 1995, Vol 76, 151-7.
Rothwell J. Control of human voluntary movement. Chapman and Hall, 1994, New York, NY

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