FALL RISK ESTIMATION OF COMMUNITY-DWELLERING ELDERLY USING INVARIANT DENSITY ANALYSIS

Pilwon Hur[1], Hyun Gu Kang[2], Lewis A. Lipsitz[3], and Elizabeth T. Hsiao-Wecksler[1]

[1] Mechanical Science & Engineering, University of Illinois at Urbana-Champaign, Urbana, IL
[2]Kinesiology & Health Promotion, California State Polytechnic University, Pomona, CA
[3]Institute for Aging Research, Hebrew SeniorLife; Harvard Medical School; Beth Israel Deaconess Medical Center, Boston MA

E-mail: phur2@illinois.edu, ethw@illinois.edu Web: www.mechse.uiuc.edu/research/hsiao-wecksler/

INTRODUCTION

Prediction of fall risk of frail and older adults using quiet-stance postural sway data has been the goal of numerous studies [1]. These studies generally used traditional center of pressure (COP) measures (swept area, sway velocity). However, these parameters do not provide insight into the physiological system as a whole. We recently developed invariant density analysis (IDA), which provides new insight into the long-term behavior of COP data [2]. It has been shown to successfully differentiate postural sway behaviors between young, middle, and older adults [2] and recurrent and non-recurrent elderly fallers [3]. We found that 4 out of 5 IDA parameters were significantly different between the faller and non-faller groups [3]. Some traditional measures (TRAD) and stabilogram diffusion analysis (SDA) parameters were found to be significantly different between the two groups [3].

In this study, we examined whether IDA parameters have the ability to better predict fall risk of community-dwelling older adults through a fall-risk prediction model when compared to other metrics of postural sway (TRAD and SDA) and clinical balance measures of Berg and short physical performance battery (SPPB) scores. We also evaluated correlation relationships among these parameters.

METHODS

Experiment

Subject data were obtained from the MOBILIZE Boston Study, a prospective cohort study of 765 community-dwelling elderly [4]. After excluding for insufficient falls follow-up data from 304 non-recurrent fallers (< 2 falls during the first year) and 140 recurrent fallers (≥ 2) were analyzed. Anterior-posterior (AP) and medial-lateral (ML) COP data, Berg and short physical performance battery (SPPB) test scores were collected at baseline. Subjects were asked to stand quietly on a force plate (Kistler, Amherst, NY, sampled at 240 Hz) for five 30s trials with their eyes open. COP data were analyzed using IDA, TRAD, and SDA methods.

IDA analysis

IDA is a stochastic analysis tool for COP data using a Markov-chain model. The invariant density is the eventual probability distribution of finding the COP at any given distance away from the centroid. Five IDA parameters characterize the invariant density. They describe the largest probability of COP staying in a given state (*Ppeak*), how far the COP drifts on average (*MeanDist*), how far the COP reaches out (*D95*), how fast the COP distribution becomes stationary (*EV2*), and how random the COP moves (*Entropy*). In brief, *MeanDist*, and *D95* are related to long-term sway, *Ppeak* and *Entropy* are related to randomness, and *EV2* is related to convergence rate.

Parameters

Postural sway parameters including IDA, TRAD and SDA, and clinical balance measures of Berg and SPPB scores were computed and collected for data analysis.

Fall risk estimation model

Discriminant function analysis (MATLAB) was used to develop fall-risk prediction models to classify recurrent and non-recurrent fallers. Separate models were developed to assess the ability of each type of balance measure - postural sway parameters (IDA, TRAD, and SDA) and clinical balance measures (Berg, SPPB) - for classifying groups of recurrent fallers and non-recurrent fallers. Data were preprocessed such that all parameters had the same variance and were uncorrelated to each other by Mahalanobis transformation. Half of the dataset was chosen randomly for the training set, and the other half for the validation set. Receiver Operating

Characteristic (ROC) analysis was used to compare accuracy and sensitivity of each model.

Correlation analysis

In order to investigate correlation between IDA, TRAD, SDA, and clinical balance measures, Pearson correlation was performed (SPSS Inc). In order to further understand how each parameter affects fall risk, principle component analysis was performed (SPSS Inc). All parameters that showed statistically significant differences between the two groups of recurrent fallers and non-recurrent fallers were used (see [3]). These include *Ppeak*, *MeanDist*, *D95*, *EV2*, *Entropy* from IDA parameters; maximum distance in radial (Rad) direction (*Max_Dist_Rad*), standard deviation in AP direction (*Stdev_AP*), range in AP direction (*Range_AP*), total power in AP direction (*Total_Power_AP*), and area of the stabilogram within a 95% confidence circle (*Area_95%_Circle*) from TRAD parameters; and short-term diffusion coefficient in Rad direction (*DS_Rad*), critical mean square displacement in AP direction (*jc_AP*), from SDA; and Berg and SPPB scores from clinical balance measures.

RESULTS/ DISCUSSION

Accuracies of separate fall risk prediction models based on IDA, TRAD, SDA, or clinical balance measures as determined by ROC analysis are given in Table 1. Accuracy of the IDA model was better by more than 2 % compared to those of other models, suggesting that IDA parameters maybe more sensitive in assessing fall risk.

Accuracies of each model seem relatively low (Table 1). This might suggest that postural sway information itself from quiet stance may not capture the whole spectrum of fall risk. It has been found that factors such as physical strength, mental health, fall history, postural sway in extreme condition can also contribute to fall risk [1].

Correlation analysis (Table 2) found that *Stdev_AP* is highly correlated (0.8 and above) with all TRAD parameters and weakly correlated (0.2 and less) with Berg and SPPB scores. *Entropy* is highly correlated with all IDA parameters except *EV2*, and weakly correlated with Berg and SPPB, and that *EV2* is weakly correlated with Berg, SPPB scores and *DS_Rad*.

Since *Entropy*, *Ppeak*, *MeanDist*, and *D95* were highly correlated among themselves, and based on the interpretation of the IDA parameters, this may imply that long term postural sway and uncertainty (or randomness) of COP motion are highly correlated. All TRAD parameters used in this analysis were highly correlated. This is because all TRAD parameters in Table 2 express measures of the COP fluctuation. Interestingly, Berg and SPPB scores are almost uncorrelated with almost all postural sway parameters, suggesting that these clinical measures provide information that postural sway parameters cannot provide. Principle component analysis showed that there were three main principle components that contribute to fall risk (Table 3). The parameters that correspond to each component imply that fall risk may affect 1) postural sway or fluctuation and randomness, 2) convergence rate of COP to invariant density, and 3) performance on clinical measures (Berg and SPPB scores).

SUMMARY

IDA parameters increased accuracy of a fall-risk prediction model of community-dwelling elderly adults by more than 2 % compared to the accuracy of the other measures. Fall-risk may affect postural sway, randomness, convergence rate and the performance on clinical measures.

FUTURE WORK

Combination of parameters will be used as fall-risk predictors in order to increase model accuracy.

Table 1. Accuracies of separate fall-risk prediction models based on IDA, SDA, TRAD or CLINIC measures

	IDA	SDA	TRAD	CLINIC
Accuracy	72.0%	70.3%	69.0%	68.9%

Table 2. Parameters that showed high and low correlations

	0.8 and above	0.2 and less
Stdev_AP	*Max_Dist_Rad, Range_AP, Total_Power_AP, Area_95%_Circle*	Berg, SPPB
Entropy	*Ppeak, MeanDist, D95*	Berg, SPPB
EV2		Berg, SPPB, *DS_Rad*

Table 3. Principle components

	Components	Variance
PC1	*Total_Power_AP, Range_AP, Area_95%_Circle, Stdev_AP, Max_Dist_Rad, MeanDist, D95, Entropy*	61.3%
PC2	*EV2, Berg, SPPB*	12.6%
PC3	*Berg, SPPB*	7.8%

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