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Invariant Density Analysis of Postural Sway and Fall-risk Prediction Model of Community-Dwelling Elderly Adults

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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]. 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 centroid. Five IDA parameters characterize the invariant density. They describe the largest probability of COP staying in a state (*Ppeak*), how far COP drifts on average (*MeanDist*), how far COP reaches out (*D95*), how fast COP distribution becomes stationary (*EV2*), and how random COP moves (*Entropy*). In this study, we examined whether IDA could provide better insight into the postural control system of elderly, and predict fall risk of community-dwelling elderly through a fall-risk prediction model (FRPM).

Subject data were obtained from the MOBILIZE Boston Study, a prospective cohort study of 765 community-dwelling elderly [3]. After excluding for insufficient falls follow-up data from 304 nonrecurrent fallers (< 2 falls during the first year) and 140 recurrent fallers (≥ 2) were analyzed. Anterior-posterior and medial-lateral 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, traditional COP measures, and stabilogram diffusion analysis (SDA) [4]. One-way analysis of variance (ANOVA) was used to determine if there were differences in these COP parameters due to fall history. Discriminant function analysis was used to develop a FRPM to classify recurrent and nonrecurrent 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.

Four of five IDA parameters (*MeanDist*, *D95*, *Ppeak* and *Entropy*) were found to be significantly different ($p < 0.05$) between recurrent and nonrecurrent fallers; implying that recurrent fallers sway much wider, in a more stochastic manner, and possibly have less degree of active control to keep the COP trajectory closer to a central equilibrium point. The FRPM indicated that IDA parameters were more sensitive to discriminate groups than traditional COP, SDA, Berg and SPPB test scores. Receiver operating characteristic analysis found that IDA parameters increased model accuracy by more than 2% compared to the accuracy the other measures.

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