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A statistical approach to discriminate between non-fallers, rare fallers and frequent fallers in older adults based on posturographic data

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ABSTRACT

Background: Identification of future non-fallers, infrequent and frequent fallers among older people would permit focusing the delivery of prevention programs on selected individuals. Posturographic parameters have been proven to differentiate between non-fallers and frequent fallers, but not between the first group and infrequent fallers.

Methods: In this study, postural stability with eyes open and closed on both a firm and a compliant surface and while performing a cognitive task was assessed in a consecutive sample of 130 cognitively able elderly, mean age 77(7)years, categorized as non-fallers (N = 67), infrequent fallers (one/two falls, N = 45) and frequent fallers (more than two falls, N = 18) according to their last year fall history. Principal Component Analysis was used to select the most significant features from a set of 17posturographic parameters. Next, variables derived from principal component analysis were used to test, in each task, group differences between the three groups.

Findings: One parameter based on a combination of a set of Centre of Pressure anterior-posterior variables obtained from the eyes-open on a compliant surface task was statistically different among all groups, thus distinguishing infrequent fallers from both non-fallers ($P < 0.05$) and frequent fallers ($P < 0.05$).

Interpretation: For the first time, a method based on posturographic data to retrospectively discriminate infrequent fallers was obtained. The joint use of both the eyes-open on a compliant surface condition and this new parameter could be used, in a future study, to improve the performance of protocols and to verify the ability of this method to identify new-fallers in elderly without cognitive impairment.

1. Introduction

Falls are a leading cause of disability, injury, and death in elderly people and represent a major public health problem with substantial medical and economic consequences. Falling is a complex phenomenon and, as far as the elderly is concerned, both intrinsic and extrinsic risk factors must be evaluated. Poor balance is one of the major risk factors for falls among the elderly. It is clear that the risk of falls and, consequently, the event itself increase with advancing years. About 35–40% of adults aged over 65 years fall at least once a year and the incidence is much higher in those people aged over 80 years (Moylan and Binder, 2007; Piirtola and Era, 2006). The significant increase in the elderly population, as shown by projections (33.7% in 2050), call for greater attention to be paid to falls, in order to implement an appropriate strategy to limit their occurrence and the severity of consequences, both in terms of costs and welfare (Moylan and Binder, 2007).

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Many functional performance-based tests were developed to quantify the risk of falls more objectively. Gait or balance tests are frequently used in clinics and include the Timed Up and Go test (TUG) (Podsiadlo and Richardson, 1991), the Berg Balance Scale (Berg et al., 1989), the Performance-Oriented Mobility Assessment (POMA) (Tinetti, 1986; Tinetti et al., 1988), and the Functional Reach (FR) test (Duncan et al., 1992).

In addition to clinical assessment, instrumental measures of postural steadiness can be used to characterize the dynamics of the postural control system in maintaining balance during quiet or perturbed standing (Pajala et al., 2008). In the first case, postural steadiness is most often assessed with measures based on the displacement of the Center of Pressure (COP) using force platforms (Prieto et al., 1996; Baratto et al., 2002). Some parameters have shown that balance tests based on force platform measurements are sensitive to differences in balance among young, middle-aged and elderly subjects, indicating changes in balance among the latter. However, single COP-related variables do not predict falls (Piirtola and Era, 2006). This is particularly true when reference is made to classic postural parameters that are mainly descriptive of the geometric characteristics of the COP trajectory (Prieto et al., 1996).

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Though posturography is experimentally simple, posturographic parameters are characterized by a large variance and a limited repeatability when single measures are used (Fioretti et al., 2004), thus limiting the possibility of identifying group differences between, e.g., non-fallers and (non recurrent) fallers, where a reduced effect-size can be reasonably supposed. To try to fill this gap and, at the same time, to reduce the dimensionality of the posturographic data set, the statistical technique of principal component analysis (PCA) may be helpful. In fact, the central idea of PCA is to reduce the dimensionality of a data set, consisting of a large number of interrelated variables, while retaining its variation as much as possible (Jolliffe, 1986). In the present case, PCA was used as a starting point to define new PCA-derived parameters with a higher discriminant value than classic posturographic parameters.

This study adopts a retrospective approach to analyze the association between the fall history of a large sample (130 subjects) of elderly people without dementia, classified in three groups (non-fallers, infrequent fallers and fallers), and the values of new PCA-derived posturographic parameters. Each subject was tested in different visual, proprioceptive and cognitive conditions in order to determine which experimental test model is able to distinguish among the three categories of subjects analyzed. The final goal of this study is to determine, by means of posturography and the multivariate statistical analysis (PCA), a new set of parameters able to differentiate groups characterized by a different fall history.

2. Methods

2.1. Sample

The study population consisted of 130 cognitively able individuals, 52 men and 78 women, with a clinical dementia rating (CDR) ≤ 0.5 and a mean age of 77(7) years (age range 70–91 years), who were seen consecutively at the Memory Clinic of the Regional Hospitals of Mendrisio and Lugano, Switzerland. Subjects with dementia were deliberately excluded from the study as they are already at high risk of falling due to their pathological condition, and thus no further screening procedure is needed.

2.2. Clinical evaluation

A standard assessment was delivered to all patients, according to the CERAD (Consortium to Establish a Registry for Alzheimer's Disease) protocol, including: clinical history (event, yes/no); measurement of cognition with the Mini Mental State Examination (MMSE); a complete battery of neuropsychological tests; fall-history; measurement of functional ability, such as basic (BADL) and instrumental activities of daily living (IADL) scores and Gait and Balance performance on Tinetti's Performance Oriented Mobility Assessment (POMA). See Fillenbaum et al. (2008) for further details on these scales. The demographic, clinical and functional characteristics of the sample are reported in Table 1.

Table 1
Mean values (standard deviation) of demographic, clinical and functional characteristics of the samples.

	NF (n = 67)	IF (n = 45)	FF (n = 18)
Age	79 (5)	79 (6)	81 (6)
Sex	29 M, 38 F	19 M, 26 F	4 M, 16 F
Height (m)	1.67 (0.10)	1.63 (0.08)	1.58 (0.05)[b]
Weight (kg)	69 (14)	64 (14)[a]	70 (16)[b]
Body mass index (kg m^{-2})	26.3 (4.9)	23.9 (3.8)[a]	28.2 (7.2)[b]
Mini mental state evaluation	26 (3)	25 (3)	25 (3)
IADL	8 (16)	12 (11)[a]	21 (23)
POMA, gait score	11	11	10
POMA, balance score	14	13	14

[a] IF significantly different from NF. $P < 0.05$.
[b] FF significantly different from IF. $P < 0.05$.

2.3. Fall history

According to the hospital standard procedure, subjects' fall-history in the last year before the enrolment in the study was collected during the clinical assessment and stored according to three default classes: 0 falls, 1–2 falls and more than 2 falls. One hundred and thirty subjects were categorized as non-fallers (NF, N = 67, mean age 79(5)), infrequent fallers (IF, one or two falls, N = 45, mean age 79(6)) and frequent fallers (FF, more than two falls, N = 18, mean age 81(6)), based on their fall-history in the last year before the enrolment in the study.

2.4. Instrumentation

Posturographic data were acquired by means of a piezoelectric force plate (Kistler 9281C, Kistler, Winterthur, Switzerland) in Mendrisio and a strain-gage based force plate (AMTI OR-6, Watertown, MA, USA) in Lugano. In both cases, the acquisition was performed by using Bioware software (Kistler, Winterthur, Switzerland) at the sampling frequency of 100 Hz.

2.5. Experimental procedure

Each subject completed a sequence of five 30-s tasks as follows: standing with eyes open on a firm surface (EOFS); standing with eyes closed on a firm surface (ECFS); standing with eyes open on a firm surface while performing a cognitive task (i.e. counting backward by steps of seven) referred to as dual task (DTFS); standing with eyes open on a compliant surface (EOCS) and standing with eyes closed on a compliant surface (ECCS). The compliant surface was obtained by placing a (40 × 40 × 3 cm) viscoelastic gel pillow (Elastil II, Laboratories Escarius, La Courneuve, France) on the force plate (Merlo et al., 2012).

Seventeen posturographic parameters (PP) were taken into consideration: 15 referring to the article by Prieto et al. (1996), and 2 as described in Baratto et al. (2002). Their definitions are given in Table 2.

2.6. Statistical analysis

For each clinical, functional and posturographic parameter, the Kruskal–Wallis test was applied to detect statistically significant differences ($P < 0.05$) among NF, IF and FF groups. Post-hoc comparisons (by Wilcoxon Rank Sum test) were carried out after a significant Kruskal–Wallis result (Table 1). The mean values and the standard deviation of the computed parameters, the Kruskal–Wallis test results, together with the post-hoc comparison (by Wilcoxon Rank Sum test), are shown in Table 3.

Principal component analysis (PCA) was used to select the most significant features among the set of parameters that characterize the posture maintenance task. For each task, PCA was applied to the complete parameter data set considering all subjects in a unique data set. As a result of this phase, we obtained a certain number of principal components (PCs). Moreover, for each PC and posturographic parameter, PCA calculated a component score (CS) representing the value of the original PP in the new reference base given by the principal components. Subsequently, the minimum number of principal components (PCs) considered as significant was determined using the Kaiser criterion, i.e. only PCs with an associated eigenvalue greater than 1 were taken into account. Varimax rotation was performed to obtain a group of homogeneous and significant variables (i.e. the loadings) for each PC. For each component, the parameters with a loading value higher than 0.40, in absolute value (Jolliffe, 1986) (Table 4), were considered to be significant. The Kaiser–Meyer–Olkin (KMO) measure was used to assess the adequacy of the analysis (Cerny and Kaiser, 1977). In the present case, PCA was used as a starting point to define new PCA-derived parameters with a higher discriminant value than classic posturographic parameters. As described in Maranesi et al. (2014), for each subject