Assessment of postural control in patients with Parkinson's disease: Sway ratio analysis

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ABSTRACT

Analysis of the postural stability impairments in neurodegenerative diseases is a very demanding task. Age-related declines in posturographic indices are usually superimposed on effects associated with the pathology and its treatment. We present the results of a novel postural sway ratio (SR) analysis in patients with Parkinson's disease (PD) and age-matched healthy subjects. The sway ratios have been assessed based upon center of foot-pressure (CP) signals recorded in 55 parkinsonians (Hoehn and Yahr: 1–3) and 55 age-matched healthy volunteers while standing quiet with eyes open (EO) and then with eyes closed (EC). Complementing classical sway measure abnormalities, the SR exhibited a high discriminative power for all controlled factors: pathology, vision, and direction of sway. Both the anteroposterior (AP) and mediolateral (ML) sway ratios were significantly increased in PD patients when compared to the control group. An additional SR increase was observed in the response to eyes closure. The sway ratio changes documented here can be attributed to a progressive decline of a postural stability control due to pathology. In fact, a significant correlation between the mediolateral SR under EO conditions and Motor Exam (section III) score of the UPDRS was found. The mediolateral sway ratios computed for EO and EC conditions significantly correlated with the CP path length ($r = .87$) and the mean anteroposterior CP position within the base of support ($r = .38$). Both indices reflect postural stability decline and fall tendency # in parkinsonians. The tremor-type PD patients ($N = 34$) showed more pronounced relationships between the mediolateral SR and selected items from the UPDRS scale, including: falls (Kendall *Tau* = .47, $p < .05$), rigidity (.45, $p < .05$), postural stability (retropul-

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sion) (.52), and the Motor Exam score (.73). The anteroposterior SR correlated only with tremor (Kendal *Tau* = .77, *p* < .05). It seems that in force plate posturography the SR can be recommended as a single reliable measure that allows for a better quantitative assessment of postural stability impairments.

1. Introduction

Poor postural balance is one of the major risk factors associated with falling in patients with Parkinson's disease (Ashburn, Stack, Pickering, & Ward, 2001; Benatru, Vaugoyeau, & Azulay, 2008; Koller, Glatt, Vetere-Overfield, & Hassanein, 1989; Playfer, 2001; Visser et al., 2003). The force platform technique has been widely used as a tool to assess balance during the quiet stance task. In this technique the postural stability is inferred empirically from systematic changes in the descriptive center of foot-pressure (CP) measures (Błaszczyk, 2008; Piirtola & Era, 2006; Raymakers, Samson, & Verhaar, 2005; Rocchi, Chiari, Cappello, & Horak, 2006; Visser et al., 2003). Since the causes of postural balance impairments in PD are multifactorial and the parkinsonian population is diverse, there is likely to be no homogeneous effects on postural control (Benatru et al., 2008). The observed age-related declines in posturographic indices are usually superimposed on effects associated with the pathology and its treatment. Likewise, the effects of PD on postural sway characteristics appear unclear, with studies reporting either increases (Błaszczyk, Orawiec, Duda-Kłodowska, & Opala, 2007; Gregoric & Lavric 1977), decreases (Horak, Nutt, & Nashner, 1992), or no differences (Schieppati & Nardone, 1991; Viitasalo et al., 2002).

Schieppati and Nardone (1991) analyzed several CP measures in PD patients including mean CP position, average sway area, and length of sway path while standing quiet with eyes open or closed. The only significant finding in PD patients was represented by a shift in the mean position of the CP. The more affected patients were shifted forwards compared to the controls. They also found that the mean CP position correlated with severity of the disease on the Webster scale. The same effect was also observed in our previous studies (Błaszczyk et al., 2007). The shifted mean CP position in parkinsonians, which reflects their flexed posture, was significantly greater compared to the healthy control subjects. The shifted mean CP position in parkinsonians exhibited a high sensitivity to visual conditions. These results support the hypothesis that the anterior margin of stability may be markedly reduced in parkinsonians (Schieppati, Hugon, Grasso, Nardone, & Galante, 1994; Błaszczyk et al., 2007; Stack, Ashburn, & Jupp, 2005; van Wegen, van Emmerik, Wagenaar, & Ellis, 2001).

There is also growing evidence for the hypothesis that increased lateral sway has been unambiguously associated with an increased risk of falling in parkinsonians (Bosek, Grzegorzewski, Kowalczyk, & Lubiński, 2005; Błaszczyk et al., 2007; Mitchell, Collins, DeLuca, Burrows, & Lipsitz, 1995; Viitasalo et al., 2002). The CP measures, such as the mediolateral path length and the ML sway range, correlate significantly with disease severity rated both by the Hoehn and Yahr Disability Scale as well as by the Motor Section of the Unified Parkinson Disease Rating Scale (Błaszczyk et al., 2007). Taken together, these findings suggest that in Parkinson's disease at least two spontaneous sway indices, lateral sway measures and mean CP position, may provide veridical evaluation for postural stability deficits and the risk of falling associated with the impairments. However, all the spatio-temporal sway measures are very sensitive to experimental design and data recording parameters. In particular, sampling frequency and filtering of the CP signals have a direct impact on sway path length, CP velocity and acceleration (Błaszczyk, 2010). Experimental protocols, e.g., length of a sampled record (duration of a trial), which vary substantially from laboratory to laboratory, strongly affect the spatio-temporal sway measures, making the results incompatible. Therefore, in the present analyses we focused on a new measure, i.e., the sway ratio (SR) that seems superior to the conventional sway indices in interpretation and at the same time does not possess the drawbacks of the traditional sway measures (Błaszczyk, 2008). As a normalized measure, the SR is insensitive to the length of the sampled CP record and to a signal sampling frequency. The SR combines features of both spatio-temporal and nonlinear postural