Gait & Posture 60 (2018) 50–54

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Spatial orientation and postural control in patients with Parkinson's disease

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ARTICLE INFO

Keywords:
Parkinson's disease
Subjective vertical orientation
Horizontal orientation
Sagittal orientation
Postural control

ABSTRACT

Postural instability is one of the most disabling and risky symptoms of advanced Parkinson's disease (PD). The purpose of this study was to investigate whether and how this is mediated by a centrally impaired spatial orientation. Therefore, we performed a spatial orientation study in 21 PD patients (mean age 68 years, SD 8.5 years, 9 women) in a medically on condition and 21 healthy controls (mean age 68.9 years, SD 5.5 years, 14 women). We compared their spatial responses to the horizontal axis (Sakashita's visual target cancellation task), the vertical axis (bucket-test), the sagittal axis (tilt table test) and postural stability using the Fullerton Advanced Balance Scale (FAB). We found larger deviations on the vertical axis in PD patients, although the direct comparisons of performance in PD patients and healthy controls did not reveal significant differences. While the total scores of the FAB Scale were significantly worse in PD (25.9 points, SD 7.2 points) compared to controls (35.1 points, SD 2.3 points, $p < 0.01$), the results from the spatialorientation task did not correlate with the FAB Scale. In summary, our results argue against a relation between perceptional deficits of spatial information and postural control in PD. These results are in favor of a deficit in higher order integration of spatial stimuli in PD that might influence balance control.

1. Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder, which is associated with impairments of motor skills and postural control. Postural instability is frequent in the later stages of the disease and successful therapeutic strategies remain to be established. Plus, it is an independent risk factor for falls in PD [for review see 1]. The underlying etiology of postural instability is complex, involving various interacting neuronal systems such as the motor and sensory systems, subcortical regulatory mechanisms, and higher cortical functions implicated in mental processes [2]. Postural control is a sophisticated process based on accurate interpretation of convergent sensory information originating from the vestibular, visual, proprioceptive and auditory system. The integration of this information builds the basis of adequate motor responses to environmental changes [3]. Despite the high frequency and serious consequences of postural instability associated with PD, the physiological mechanisms underlying these postural impairments remain unclear [2].

One hypothesis for impaired postural control in PD patients is an integration failure of sensory-motor coordination in subcortical regulatory mechanisms. Accordingly, an altered balance control in patients with PD is due to a failure in central processing of sensory information provided by different sensory systems [4–6]. An alternative hypothesis is that postural instability in PD results from a defective central processing of spatial information allocated the three room axes [6–8] that has been found even in stroke patients [9]. Since movements are generated as a function of environmental changes, a cognitive integration failure of spatial information might also affect posture and motor skills. Spatial information cover the extrapersonal space defined through the vertical, horizontal and the sagittal (depth) axis. PD patients show signs and symptoms of an altered orientation on the vertical axis that is related with abnormalities in posture, postural instability and visuospatial defects in the perception of verticality and horizontality [10]. Such spatial abnomalies in PD can express in various ways: a divergent subjective visual vertical (SVV) perception, an altered visual perception of vertical size, an impaired postural control while maintaining upright stance, an asymmetric distribution of attention and goal-directed behavior, and a visual neglect [5,11,12]. These failures in spatial orientation depend on different experimental conditions and settings, such as an upright or tilted body position, static or dynamic, or computerized tests.

To unravel the interplay between spatial perception and postural instability in PD, we compared spatial orientation in PD patients and healthy controls. Whereas in stroke patients an impaired vertical tilt is

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https://doi.org/10.1016/j.gaitpost.2017.11.011
Received 17 May 2017; Received in revised form 31 August 2017; Accepted 11 November 2017
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behaviorally relevant [9] and visual-spatial impairments in PD has been reported, we assume that the sum of an orientation bias in multiple room axes might be more relevant in PD patients. Therefore, we analyzed spatial orientation on each of the three room axes (vertical, horizontal, sagittal) separately. If the summation of a spatial orientation bias on different room axes triggers deficits in postural control in PD, a global score for balance control should be explained by the performance of spatial tests examining the three room axis. Therefore a comprehensive investigation of postural control was performed. In summary the following main questions were addressed: (1) is there an impairment (uncertainty) in spatial orientation on each of the three room axes in patients with Parkinson's disease? (2) what is the impact of summation of spatial orientation bias on each room axes on balance control in PD?

2. Methods

2.1. Participants and procedure

Twenty-one patients with idiopathic PD and twenty-one healthy controls (HC) were included in the study. Inclusion criteria for the PD group were a reliable PD diagnosis according the brain bank criteria [13]. Exclusion criteria for PD patients were deep brain stimulation and any neurological diseases other than PD. Pisa Syndrome is another exclusion criterion because a significant association of Pisa Syndrome with altered visuoperceptual functions and postural performance had been shown [14]. Exclusion criteria for both groups were dementia (Montreal Cognitive Assessment German adaptation < 21 points [15]) and clinical signs of vestibular or cognitive diseases [16]. Participants' characteristics are summarized in Table 1. HC were matched to the patients according age (+/− 3 years). PD severity was rated according to Hoehn and Yahr classifications and Unified Parkinson's Disease Rating Scale (UPDRS) motor scores [17]. All patients were tested in the on state using their regular antiparkinsonian medication. The study was approved by the local ethic committee of the Christian-Albrecht-University, Kiel and was conducted in fully accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the experiment. Participants were tested for spatial orientation in a randomized order to control for possible sequence effects. Spatial perception was tested separately on each room axis for each participant.

Table 1
Participant characteristics (N = 42).

	PD patients (n = 21)	Control group (n = 21)	*Sig.*
Age (years)	68 ± 8.5 (range 54–82)	68.9 ± 5.5 (range 60–80)	p = 0.445
Sex (m/w)	12/9	7/14	p = 0.063
Disease duration (years)	7.28 ± 4.4 (range 0.5–16)	–	–
UPDRS II score	8.6 ± 5.0 (range 1–19)	–	–
UPDRS III score (Med ON)	21.8 ± 9.6 (range 10–42)	–	–
H&Y stage	2.5 ± 0.5 (range 2.0-3.0)	–	–
Retropulsion (UPDRS #30)	0: n = 12 1: n = 8 2: n = 1 (range 0–2)	–	–
FAB score ≤25	n = 12	n = 0	$p < 0.001$

Note. Values represent mean ± SD; PD: Parkinson's disease; UPDRS: Unified Parkinson's Disease Rating Scale; H&Y: Hoehn-Yahr. FAB: Fullerton Advanced Balance Scale; a total score ≤25 indicates a high risk for falls [24].

2.2. Experimental setting

As there are no official thresholds for the measurements used in this study indicating a clinically relevant impairment in spatial perception we used significant differences between both tested groups to prove our hypotheses.

2.2.1. Spatial orientation on the horizontal axis

Spatial orientation on the horizontal axis was measured by Sakashita's visual target cancellation task [18]. Each participant was tested in a calm and dimly illuminated room and was seated about 55 cm in front of a 22-inch monitor. Five vertically arranged white lines appeared on a black background. A small defect (0.3 cm × 0.4 cm) on each line was used as a target and appeared randomly on one of three positions and on one of the five lines. The interstimulus interval was 2 to 5 s. Participants were instructed to press the space bar of the keyboard as quickly as possible whenever they perceived the defect. Each trial started with 16 exercise stimuli followed by 89 testing targets. To control any motor confounding variables, the task was performed using the right and the left hand separately. Visual distribution of attention in both hemifields was calculated by building the quotients of the reaction times of lateralized targets (e.g. line 1, Fig. 1A) in relation to the reaction times of centrally presented targets (line 3, Fig. 1B) for each hand. This quotation reflects the distribution of attention on the horizontal axis. Significant differences of the quotients between and within groups define a visual neglect and thus a failure of spatial orientation on the horizontal axis.

2.2.2. Spatial orientation on the vertical axis

The binocular subjective visual vertical (SVV) was tested with the bucket-test [19]. Participants were instructed to turn the bucket to adjust a visible line on the ground of it from a horizontal into a vertical position; three times clockwise (CW) and three times counterclockwise (CCW). No time limit was imposed. In the absence of an established clinically relevant SVV, we used significant differences between the means of both groups to define a spatial disorder on this room axis. We hypothesized that the average deviations from the objective visual vertical should be significantly larger in patients with PD than in HCs according to the results by Khattab and colleagues [20].

2.2.3. Spatial orientation on the sagittal axis

Perceptual disturbances on the sagittal axis were assessed by using a tilt table. Subjects were strapped on it and slowly passively moved from a starting position of 45° towards a horizontal body position (0°) measuring postural sense in the sagittal plane. They had to indicate whenever they think to lay in a bodily horizontal position. To exclude cues for visual orientation, participants wore a sleeping-mask. This procedure was repeated three times. Afterwards, the starting position was a negative angle of −8.7°. This angle was utilized because it was not possible to turn the table lower. Starting from a negative position with head down, participants were slowly turned up and had to say 'stop' again when they supposed being in a horizontal position. This condition was also repeated three times. After each run, the objective horizontal was shown to the participants. Blood pressure was measured before and after each run. We employed the difference of the values between both groups to detect a disturbance in a perception on the sagittal axis. We expected that the averaged deviations from the objective value (0°) were significantly larger in both testing conditions in PD than in controls.

2.2.4. Postural control

Postural control was measured by the German version of the Fullerton Advanced Balance Scale (FAB) [21]. This is a validated clinical test and consists of ten balance tasks [22]. Scoring is based on a 5-point scale. A score of 0 represents a very poor performance level and a score of 4 an adequate postural performance.

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