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Reactive but not predictive locomotor adaptability is impaired in young Parkinson's disease patients

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ABSTRACT

Background: Gait and balance disorders are common in Parkinson's disease (PD) and major contributors to increased falling risk. Predictive and reactive adjustments can improve recovery performance after gait perturbations. However, these mechanisms have not been investigated in young-onset PD.
Objective: We aimed to investigate the effect of gait perturbations on dynamic stability control as well as predictive and reactive adaptability to repeated gait perturbations in young PD patients.
Methods: Fifteen healthy controls and twenty-five young patients (48 ± 5 yrs.) walked on a walkway. By means of a covered exchangeable element, the floor surface condition was altered to induce gait perturbations. The experimental protocol included a baseline on a hard surface, an unexpected trial on a soft surface and an adaptation phase with 5 soft trials to quantify the reactive adaptation. After the first and sixth soft trials, the surface was changed to hard, to examine after-effects and, thus, predictive motor control. Dynamic stability was assessed using the 'extrapolated center of mass' concept.
Results: Patients' unperturbed walking was less stable than controls' and this persisted in the perturbed trials. Both groups demonstrated after-effects directly after the first perturbation, showing similar predictive responses. However, PD patients did not improve their reactive behavior after repeated perturbations while controls showed clear locomotor adaptation.
Conclusions: Our data suggest that more unstable gait patterns and a less effective reactive adaptation to perturbed walking may be a disease-related characteristic in young PD patients. These deficits were related to reduced ability to increase the base of support.

1. Introduction

Postural instability is a major problem for Parkinson's disease (PD). The falling rate of PD patients is five times higher than that of age-matched controls, having a dramatic impact on patient's mobility and quality of life [1]. Nearly half of these falls occur during dynamic tasks, such as walking [2]. Parkinsonian gait is characterized by less foot clearance [3], reduced walking velocity and shorter stride length [4]. These deficits in the typical PD gait pattern may result in reduced stability during normal walking. However, gait analyses are usually made while walking on firm and predictable surfaces, which is not representative of the variable real-world circumstances [5]. Unexpected gait perturbations are present in daily gait episodes and have been shown to decrease recovery performance leading to a higher occurrence of falls in older individuals [6]. In PD patients, given the above-mentioned gait impairments, the risk of falling could be exacerbated under those conditions that challenge postural stability [5].

From a biomechanical point of view, there are three mechanisms responsible for maintaining postural stability after perturbations: (a) increasing the base of support (BS), (b) counter-rotating segments around the center of mass (CM), and (c) applying an external force [7]. Furthermore, recovery performance can be modified by predictive and reactive adaptive behavior. Reactive adjustments rely on the detection of unexpected perturbations and depend on sensory information received during the movement [8]. On the other hand, predictive adjustments are based on the available knowledge about the intended movement [8,9] and can improve dynamic stability by counteracting an expected perturbation during the ongoing movement, thus reducing its consequences [10,11].

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While elderly PD patients rarely demonstrate locomotor adjustments during transitional periods, such as turning [1], obstacle clearing [12], and gait initiation [13], it is evident that a certain ability to adapt to new walking conditions and to store new walking patterns is present in PD [14,15]. Nevertheless, this adaptability is reduced, as compared to healthy controls [14]. PD patients also show deficits in proprioception [16], which may result in reduced adaptation potential to changing conditions (i.e. gait perturbations). Therefore, PD may impair reactive as well as predictive postural adjustments during gait, as sensory information is essential for the planning and execution of postural responses to maintain dynamic stability during perturbed walking [8].

Age also plays a significant role in gait stability. The results from new studies on elderly PD patients are not directly transferable to young patients, since it is well known that the ability to control stability deteriorates during the natural aging process [6,17]. There is a growing number of young-onset PD patients (under 51 years old) [18] suffering from gait and stability impairments [19]. However, since the mean age of disease onset is 65 years, very little is known about young PD patients' stability performance during perturbed walking. Identifying the deficits in dynamic stability control during disturbed walking, which relates to the underlying disease process in young-onset PD, would contribute to the development of adequate training interventions aimed at reducing falls in young patients.

To date, there is no information about young PD patients' locomotor adaptability in response to repeatedly perturbed walking. Therefore, this study aimed to investigate the effect of unexpected gait perturbations on dynamic stability control in young PD patients (on average ~48 yrs.), compared to age-matched healthy controls, and to examine the reactive and predictive adaptability following repeated perturbations. We hypothesized less stable walking, greater consequences on stability after an unexpected perturbation and lower predictive as well as reactive locomotor adaptability in PD patients, compared to controls.

Table 1
Anthropometric data, age at disease-onset and stage in the Hoehn & Yahr Parkinson scale (H&Y) for the control and the PD groups (means ± SD).

	Controls ($n = 15$)	PD patients ($n = 25$)
Age [yrs.]	47 ± 5	48 ± 5
Body mass [kg]	78.0 ± 14.6	77.6 ± 16.6
Body height [cm]	174 ± 12	172 ± 8
Body mass index [kg/m^2]	25.3 ± 4	25.9 ± 4.5
Age at disease-onset [yrs.]		42 ± 6
H&Y scale		2.0 ± 0.7

There were not statistically significant differences ($p > 0.05$) in any of these parameters between groups.

2. Methods

2.1. Participants

Fifteen healthy adults and twenty-five young patients with idiopathic PD participated in this study (Table 1). Patients were not included in the study if they had a history of any other neurological or orthopedic disorders. Individuals were examined during the ON phase while taking a daily dose of dopaminergic medication ranging from 150 to 500 mg (levodopa) and 2–20 mg (dopamine–agonists). Controls were matched to the PD patients with respect to age, anthropometrics and sport activity level. Sport activity was quantified as hours per week of regular sport activity in the past year. All participants provided informed consent for protocols approved by the university ethics committee.

2.2. Experimental protocol

The participants performed 11 walking trials on a walkway ($12 \times 0.6 \times 0.2$ m^3) which included an exchangeable element ($75 \times 60 \times 20$ cm^3) that was hidden with a cover sheet in order to be able to change the surface (hard/soft) without the knowledge

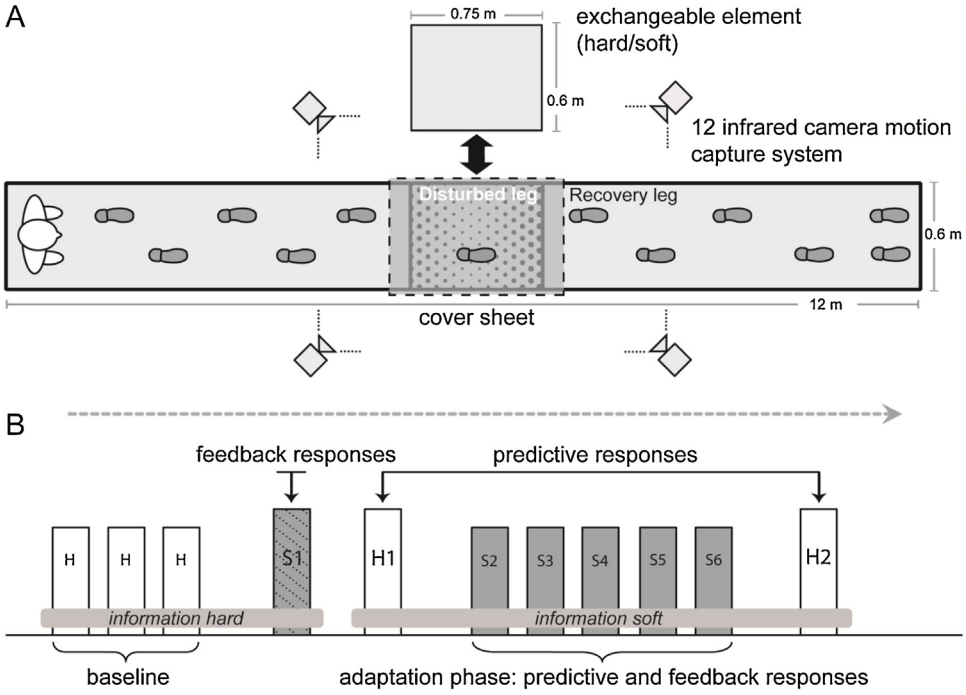

Fig. 1. Experimental setup and protocol. (A) The walkway included one covered, exchangeable element, which allowed changing the surface condition from hard to soft and vice versa without the knowledge of the participants. (B) Three baseline trials on the hard surface (H), were followed by one unexpected soft surface trial (*S1*). The next unannounced hard surface trial (*H1*) and the last hard surface trial (*H2*) after five soft trials were used to analyze predictive responses (after-effects). The soft surface trials (S2 to S6) documented the adaptation phase. The participants started the baseline trials with the information that they would have to expect a hard surface and continued after the first soft trial with the new information that the surface would stay soft.