Gait & Posture 57 (2017) 299–304

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Postural motor learning in Parkinson's disease: The effect of practice on continuous compensatory postural regulation

Karen Van Ooteghem[a,*], James S. Frank[a], Fay B. Horak[b,c]

[a] Department of Kinesiology, University of Waterloo, 200 University Ave. W., Waterloo, ON, N2L 3G1, Canada
[b] Department of Neurology, Oregon Health and Science University, 3181 SW Sam Jackson Park Rd., Portland, OR, 97239-3098, USA
[c] Research Dept., Portland VA Medical System, 3710 SW US Veterans Hospital Rd., Portland, OR, 97239-9264, USA

ARTICLE INFO

Keywords:
Parkinson's disease
Posture
Continuous perturbation
Motor learning
Automatic postural response

ABSTRACT

Introduction: Although balance training is considered the most effective treatment for balance impairments in Parkinson's disease (PD), few studies have examined if learning for balance control remains intact with PD. This study aimed to determine if learning for automatic postural responses is preserved in people with PD.
Methods: Eleven participants with moderate PD (68 ± 6.4 years; H & Y: 2–3) on their usual medication maintained balance on a platform that oscillated forward and backward with variable amplitude and constant frequency. Participants completed 42 trials during one training session, and retention and transfer tests following a 24-h delay. Performance was measured by comparing spatial and temporal measures of whole-body centre of mass (COM) with platform displacements. Learning was compared between participants with PD and previously reported, age-matched older adults (Van Ooteghem et al., 2010).
Results: Although postural responses in participants with PD were impaired compared to control participants, a majority of PD participants improved their postural responses with practice as revealed by reduced COM displacements and improved phase relationships between COM and platform motion. Rates of improvement were comparable between groups demonstrating preserved adaptive capacity for participants with PD. Similar to control participants, the PD group moved toward anticipatory COM control as a strategy for improving stability, exhibited short-term retention of performance improvements, and demonstrated generalizability of the learned responses. Rate of improvement with practice, but not retention, was related to severity of motor impairments.
Conclusions: Patients with moderate PD on medication demonstrate retention of improvements in automatic postural responses with practice suggesting that intrinsic postural motor learning is preserved in this group.

1. Introduction

Although balance training is considered the most effective rehabilitative treatment for balance impairments in Parkinson's disease (PD), few studies have examined whether the ability to learn a balance task is affected by PD [1–5] and only recently, has attention been given to whether or not PD impairs motor learning for automatic postural responses (APRs) [2,6,7]. APRs occur in response to externally-triggered disruptions to stability such as a slip or during continuous perturbations such as standing on a moving tram. The APR can involve feet-in-place responses when adjusting to small destabilizing forces, e.g. riding a tram, or single or multiple steps when reacting to a large perturbation, e.g. a slip. The goal of the present study was to examine if postural motor learning for a continuous, compensatory balance task, quantified by improved postural stability with training on an oscillating support surface, is preserved in patients with moderate PD.

Motor learning and motor control are often viewed as separate processes and although their independence is debatable (see [8] for review), the distinction between performance and learning suggests that the motor control impairments observed in PD do not necessarily predict loss of ability to learn a motor task. Motor learning is thought to be largely non-declarative, often occurring via trial and error without conscious awareness (e.g. learning to ride a bike) [9,10]. Converging evidence suggests that non-declarative learning depends upon the basal ganglia and dopamine [8,11–13]. Although few reports on postural motor learning in PD are available, existing studies have focused on *volitional* balance control, demonstrating mixed results related to longer-term retention of the acquired skill [1,3–5]. Recently, our group has demonstrated learning for transient postural recovery (protective stepping) in individuals with PD [6,7]. It is currently unknown how PD affects postural motor learning of a compensatory balance task requiring continuous postural regulation or how PD affects postural

* Corresponding author.
E-mail address: kvanoote@uwaterloo.ca (K. Van Ooteghem).

http://dx.doi.org/10.1016/j.gaitpost.2017.06.021
Received 15 May 2015; Received in revised form 20 June 2017; Accepted 22 June 2017

motor learning when the balance task lacks predictability.

Previously, we demonstrated preserved capacity for improvements in compensatory balance control in healthy older adults who underwent training on an oscillating platform with varying degrees of displacement, followed by retention testing 24-h later [14,15]. These improvements existed despite poorer postural stability in older, versus younger, participants. Furthermore, we demonstrated that performance improvements in both old and young adults possessed a degree of generalizability important for positive transfer of skill. In the current study, we hypothesize that participants with PD on their medication, when compared to healthy, aged-matched control participants, will exhibit impaired performance but preserved postural motor learning as demonstrated by a) acquisition of adaptive APRs at a rate comparable to healthy, control participants and b) retention of performance improvements. We also hypothesize that participants with PD will demonstrate lack of transfer to a modified version of the task suggesting limits in the generalizability of the acquired skill.

2. Methods

2.1. Participants

Eleven adults with idiopathic Parkinson's disease (4 males, 7 females) volunteered to participate. Participants ranged in age from 60 to 79 years (68 ± 6.4) and had mild to moderate PD as determined by a movement disorders neurologist (Hoehn and Yahr: 2–3). All participants took their anti-Parkinson medication within two hours prior to testing with no wearing off reported. The motor subscale of the Unified Parkinson's Disease Rating Scale (UPDRS) was administered prior to testing and ranged from 14.5–56 (Table 1). Participants were also assessed for freezing of gait (FOG) [16] and activities-specific balance confidence (ABC) [17] (Table 1). Participants were free of orthopaedic, psychological, or other neurological disorders that could affect their ability to perform the task. This study was approved by the University of Waterloo and Oregon Health and Science University research ethics boards. All participants provided informed consent prior to data collection. In addition, data from eleven healthy, age-matched, older adults (CTL), previously reported in Van Ooteghem et al. [15–"looped sequence" protocol], were compared with results of the participants in this study.

2.2. Procedures

The balance task required participants to stand on a hydraulically driven, servo-controlled platform that could translate horizontally forward and backward. Participants wore an unrestrictive, industrial safety harness tethered to a sliding hook on an overhead rail and were asked to maintain balance while looking straight ahead with arms crossed at the chest, avoiding stepping if possible. The platform oscillated at a fixed frequency of 0.5 Hz and variable amplitudes ranging from ± 0.5 cm to the largest amplitude that participants could withstand without stepping (maximum ± 15 cm).

Trials were 42-s and composed of three segments of a 14-s, seemingly random sequence of platform oscillations. All trials for a participant were identical but the participant was not informed of the repetition. Each participant had a unique sequence of platform translations, which was generated randomly from a standard pool of amplitudes (range: 0.5–15 cm). The training sequences were identical to those used for CTL participants [15]. For each participant, the maximum distance moved by the platform was scaled to a personal maximum as determined by a 20-s, constant amplitude practice trial (range: 11–15 cm; note 5/11 PD participants, but no CTL participants [15] required a reduction in perturbation amplitude). Testing consisted of six blocks of seven trials. To separate temporary effects of practice from more permanent changes in behaviour that would reflect learning, participants returned for a 3-block retention test approximately 24 h following practice. Immediately following the retention test, participants completed one block of trials containing random sequences of sinusoidal platform translations (i.e. a transfer test) to examine the generalizability of observed performance improvements. Each of the trials in the transfer block was unique; generated randomly from the standard pool. The same block of transfer trials was given to all participants.

2.3. Data recording

A Motion Analysis System (Motion Analysis Corporation, Santa Rosa, CA) with six cameras captured three-dimensional spatial coordinate information about body segment displacements and platform movement. Reflective markers were placed bilaterally on the fifth metatarsophalangeal, lateral malleolus, lateral femoral condyle, greater trochanter, anterior superior iliac spine, iliac crest, styloid process, olecranon, acromium process, and lateral mandibular joint, and on the xyphoid process. A marker was also placed on the platform. Data were sampled at 60 Hz and low pass filtered using a 2nd order, dual pass Butterworth filter with a cut-off frequency of 5 Hz. The position of the centre of mass (COM) of each body segment in the antero-posterior (AP) direction was calculated using the kinematic data and anthropometric data provided by Winter [18]. Whole body COM position (in space) in the AP direction was derived from the weighted sum of the individual segment COM locations using a custom-designed MATLAB program (Mathworks, Natick, MA).

Table 1
PD participant demographics and clinical outcomes.

Participant	Gender	Age (y)	Disease Duration (y)	Hoehn & Yahr Score	UPDRS[a] motor subscore (Day 1)	ABC[b] Score Total (mean)	Freezing of Gait Score
1	F	66	5	2.5	42	1150 (71.9)	10
2	F	65	6	2.5	56	1170 (73.1)	14
3	M	70	10	2	29	1375 (85.9)	4
4	F	72	5	3	30	1290 (80.6)	4
5	F	63	13	2	14.5	1290 (80.6)	5
6	M	62	4	2	41	1400 (87.5)	9
7	F	67	5	2	21	1537 (96.1)	6
8	F	74	5	2	31	1486 (92.9)	1
9	M	73	5	2.5	28	1225 (76.6)	13
10	M	69	11	2	48	1560 (97.5)	8
11	F	70	5	2	28.5	1255 (78.4)	9
Mean		68	6.7	2.2	33.4	1340 (83.7)	7.5
SD		4	3.1	0.34	12.2	142.8 (9.0)	4

[a] Unified Parkinson's Disease Rating Scale.
[b] Activities-Specific Balance Confidence.