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Dual Tasking During Postural Stepping Responses Increases Falls But Not Freezing In People With Parkinson's Disease

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Abstract

Purpose—Although falls in people with Parkinson's disease (PD) associate with dual tasking and freezing of gait (FoG), it is not known whether falls during dual tasking are due to FoG. This study investigated the effects of a cognitive task on the occurrence of falls and FoG when subjects with PD step in response to a postural perturbation.

Methods—Ten subjects with PD and a history of FoG as well as 10 age-matched subjects without PD stepped in response to large, backward displacements of the support surface, with and without performing a fluency task of listing items in a category. Subjects with PD performed the task in the “off” and “on” dopaminergic medication states. We recorded the percentage of trials with FoG (a lack of step in response to the perturbation), foot-lift latencies, and trials with falls into a safety harness.

Results—Dual tasking significantly increased the incidence of falls in people with PD, but subjects without PD did not fall in any condition. Dual tasking did not significantly increase trials without steps or foot-lift latencies. Falls were often coincident with a lack of step (FoG) in the single-task condition, but the increased falls with dual tasking occurred on trials with steps. Levodopa tended to decrease FoG and falls with or without dual tasking. However, medication did not significantly alter the effects of dual tasking on FoG or falls.

Conclusions—For people with PD and FoG, forward falls may not always be caused by FoG, particularly under attention-distracting conditions.

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Keywords

Parkinson's disease; posture; step initiation; dual task; attention; freezing of gait; balance; falls

Introduction

Falls in patients with Parkinson's disease (PD) are associated with, among other things, dual tasking [1] and a history of freezing of gait (FoG) [2]. Dual tasking can also elicit FoG [3]. Thus, clinicians generally assume that falling in patients with FoG, especially in the forward direction, is caused by FoG, but this assumption has never been tested.

We examined the occurrence of falls and FoG induced by backward translations of the support surface that require a forward step to regain balance in subjects with PD and marked FoG. The effect of dual-task performance on FoG and falls was quantified to test the clinical lore about falls in patients with FoG.

Methods

Subjects

Ten subjects with idiopathic PD and FoG (9 males, 1 female; mean (range) age = 66 (53-76) years) and 10 subjects without PD (9 males, 1 female; mean (range) age = 66 (57-76) years) gave informed consent to participate in the protocol approved by the local Institutional Review Board. FoG was determined by direct observation in the laboratory and the clinic by a movement disorder specialist (JN). The subjects with PD were tested “off”, after withholding their anti-parkinsonian medication overnight, and were mobile but had bradykinesia and FoG. Nine of the subjects with PD also performed the protocol while “on”, approximately one hour after taking their anti-parkinsonian medications. The subjects did not present with significant cognitive deficits (Short Blessed Test [4] scores < 8; Table 1), and they were able to sign an informed consent form and follow protocol instructions.

Protocol

Subjects took forward steps in response to a backward translation of the support surface. The task was performed under two conditions: with and without a fluency task of listing items in a category.

Subjects stood on a moveable platform with each foot on a separate force plate, looking straight ahead and with their arms at their sides. Subjects stood in an unenclosed, well-lit laboratory environment on a custom-built, moveable, force-plate system consisting of two adjacent force plates (46 cm long × 23 cm wide) imbedded within a larger structure that provided a flat, unimpeded stepping surface [5]. The subjects attempted to regain their balance in response to 10 trials of an unpredictably timed 21-cm backward translation of the force plates that had a peak velocity of 50 cm/s. The torsional forces exerted on the platform base were computed to an accuracy of $0.005 \text{ Kg-m} \pm 2\%$, 0-10Khz, by measuring the relative forces on each force plate's 4 load transducers, one mounted on each corner of the

force plates' bases. The time between trials varied unpredictably between 5-10 seconds after the subject was back in a stable upright stance position.

In random sequence, five of the 10 trials were conducted while the subjects were listing items in a stated category (with a new category chosen for each trial). Categories included lists of mountain ranges, types of fish, vegetables, states on the eastern seaboard, etc. This semantic fluency test was selected because people with FoG are sensitive to dual-task costs when performing the task during voluntary gait [6]. The subjects were instructed to "keep your balance" in both conditions.

The subjects wore a safety harness attached to the ceiling and an attendant stood beside the subjects to further protect them from falling to the ground. The harness did not provide support in upright stance, but would catch the subject midway through a fall. The attendant stood behind and to the left of the subjects and could not be observed by the subjects when they looked 12 feet straight ahead at a wall-mounted art poster. The attendant did not intervene until it was apparent that the subjects could not regain standing equilibrium. The subjects sat intermittently to rest and were instructed to ask for rest whenever needed in order to prevent fatigue.

A previous report from this study demonstrated that this protective stepping task elicits FoG with concomitant knee trembling that is a defining characteristic of FoG [7]. This previous report, however, did not consider the effects of dual tasking on falls and FoG.

Data Collection and Processing

Primary measures were the percentages of trials with FoG and with falls. We defined FoG as a trial with no step. No step was recorded when the vertical weight on a force plate never dropped to a value of zero, which would indicate that the foot did not leave the force plate. Because FoG could manifest as a delayed step, we recorded the foot-lift latency of each trial as the time after perturbation onset in which the vertical weight of a force plate fell to a value of zero. Trials with falls were recorded by visual observation during the experiment and were defined as trials in which the subjects required support by the safety harness or by the attendant standing at their side. The occurrences of FoG and falls were calculated as a percentage of five trials for each subject and each condition of stepping with or without a dual task. Foot-lift latencies were averaged by subject and condition.

Statistical Analysis

Because the distribution of the data violated the assumption of normality (as determined by Shapiro-Wilks tests), non-parametric statistics were used for all analyses. Wilcoxon Signed Rank tests evaluated differences between the single- and dual-task conditions in the occurrence of FoG and falls as well as in foot-lift latencies in order to identify the effects of the fluency task on the subjects' protective stepping responses. Because our previous report [7] already described the effects of medication on these outcome variables in the single-task condition, this report evaluated the effects of medication on differences in the outcome variables between the single- and dual-task conditions; Wilcoxon Signed Rank tests evaluated the effects of medication on changes in FoG, falls, and foot-lift latency with dual tasking. Differences were considered significant if the p-value was equal to or less than 0.05.

Results

For the group with PD, in the off medication state, performing the fluency task during protective step responses significantly increased the percentage of trials with falls ($Z_{\text{wilcoxon}} = 2.26$, $P = 0.024$) (Table 1). There were no significant changes, however, in the percentage of trials with FoG ($Z_{\text{wilcoxon}} = 0.33$, $P = 0.739$) between the conditions with and without the fluency task (Table 1). In addition, foot-lift latencies did not significantly change between the conditions with and without the fluency task: mean (95% confidence interval) latencies were 728 (516-939) ms without the fluency task and 876 (529-1222) ms with the fluency task ($Z_{\text{wilcoxon}} = 0.34$, $P = 0.739$). Although falls rarely occurred without FoG in the single-task condition, the increase in falls with dual tasking occurred despite successfully initiating a protective step (Fig. 1).

The group without PD never fell in any trial regardless of condition. Foot-lift latencies were not significantly different between the conditions with and without the fluency task: mean latencies were 683 (550-817) ms without the fluency task and 698 (557-838) ms with the fluency task ($Z_{\text{wilcoxon}} = 0.26$, $P = 0.799$).

Anti-parkinsonian medications tended to decrease FoG and falls across both single- and dual-task conditions. Medication, however, did not significantly alter the differences between single- and dual-task conditions in FoG ($Z_{\text{wilcoxon}} = 1.00$, $P = 0.317$) or falls ($Z_{\text{wilcoxon}} = 0.96$, $P = 0.336$). Mean foot-lift latencies in the on medication state were 570 (451-688) ms without the fluency task and 625 (508-743) ms with the fluency task. Medication did not significantly affect changes in foot-lift latencies between the conditions with and without the fluency task ($Z_{\text{wilcoxon}} = 0.52$, $P = 0.600$).

Discussion

The results did not support the clinical assumption that dual tasking increases the occurrence of forward falls due solely to increased FoG. The fluency task elicited a greater number of falls during protective step initiation for people with PD and a history of FoG, but dual tasking did not significantly alter the occurrence of FoG (i.e., trials without steps, or delayed foot-lift latencies when stepping occurred) during protective stepping responses. Although some individual subjects demonstrated dual-task related increases in both FoG and falls, others demonstrated larger increases in falls than in FoG or demonstrated an increase in falls with either no change in FoG or decreases in FoG. The effects of dual tasking remained consistent between the off and on medication states. Thus, persons with PD are more susceptible to falls when dual tasking during protective step initiation, but this increased susceptibility to falls is not solely because dual tasking increases the occurrence of FoG.

Our results partially contradict previous research that demonstrated an increase in FoG with dual tasking [3]. Although Spildooren and colleagues demonstrated that performing a color-classification task while performing 360-degree turns increased the occurrence of FoG, this dual-task paradigm did not increase FoG during straight-line walking or 180-degree turning. Thus, inducing FoG with dual tasking may be task specific and related to the complexity or conditions of the gait task. Dual tasking may not have increased the occurrence of FoG

during protective stepping in response to surface translations either because this study's task is triggered by a strong external cue or because it does not include the coordination required for a turn.

This study has methodological limitations to consider. First, we did not evaluate the performance of the verbal fluency task. Second, we did not record kinematics of the protective stepping response in order to evaluate step characteristics during the swing phase of the response. Third, we did not have a control group of individuals with PD but without a history of FoG for comparison. Although these limitations inhibit our ability to interpret why dual tasking affects the incidence of falls when performing protective steps to an induced loss of balance, the limitations do not impair our ability to conclude that the dual-task related increase in falls was not consistently associated with a concomitant increase in FoG.

Clinically, the results imply that even forward falls in patients with PD who present with FoG may be unrelated to FoG, and this dissociation appears more prevalent under dual-task conditions. Clinicians thus need to consider a variety of strategies in addition to addressing FoG in order to reduce falls, perhaps including instructions to the patient to avoid doing any other tasks while walking.

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Fig 1.

Frequency of falls with and without freezing of gait (FoG) during the single- and dual-task conditions as well as off and on medication.

Table 1
Falls and FoG of subjects with PD during single- and dual-task conditions, off and on medication

	Levodopa Equivalent Dose (mg/day)	Disease Duration (yr)	Short Blessed Test Score	UPDRS Motor Score (off / on)	Fall Trials Single Task (off / on)	Fall Trials Dual Task (off / on)	FoG Trials Single Task (off / on)	FoG Trials Dual Task (off / on)
PD Group Mean	1268	15	2	36 / 17	32% / 11%	52% / 22%	32% / 16%	34% / 11%
PD Group Median	1300	14	0	38 / 12	20% / 0%	50% / 0%	20% / 0%	20% / 0%
Subject 1	1750	17	0	36 / 4	0% / 0%	0% / 0%	0% / 0%	0% / 0%
Subject 2	1750	12	0	38 / 8	80% / 0%	100% / 0%	80% / 0%	100% / 0%
Subject 3	1300	22	0	39 / 12	20% / 0%	60% / 20%	20% / 0%	0% / 0%
Subject 4	1000	15	0	26 / --	0% / --	0% / --	0% / --	0% / --
Subject 5	1300	12	4	46 / 24	100% / 20%	100% / 60%	100% / 100%	60% / 20%
Subject 6	1750	21	7	36 / 14	80% / 80%	100% / 100%	80% / 40%	100% / 80%
Subject 7	800	9	0	40 / 30	20% / 0%	40% / 20%	20% / 0%	20% / 0%
Subject 8	1000	13	0	38 / 40	0% / 0%	20% / 0%	0% / 0%	20% / 0%
Subject 9	1400	12	0	23 / 9	20% / 0%	100% / 0%	20% / 0%	40% / 0%
Subject 10	625	15	4	38 / 11	0% / 0%	0% / 0%	0% / 0%	0% / 0%